U.S. Department of
Homeland Security

United States
Coast Guard

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United States Coast Guard

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COMDTNOTE 16000

SEP 29 2004

COMMANDANT NOTICE 16000

CANCELLED: SEP 28 2005

Subj: CH-3 TO COMDTINST M16000.9, MARINE SAFETY MANUAL, VOLUME IV – TECHNICAL, CHAPTER 3 – ENGINEERING SYSTEMS

1. PURPOSE. This Notice publishes a change to the Coast Guard Marine Safety Manual, Volume IV, Chapter 3.

2. ACTION. Area and district commanders, commanders of maintenance and logistics commands, and commanders of Headquarters units shall ensure compliance with the provisions of this Notice. No paper distribution will be made of this Notice. Official distribution will be via the Coast Guard Directives System CD. An electronic copy will be made available via the following web sites:

   a. The Coast Guard Directives System on the Coast Guard web:
   http://cgweb.uscg.mil/g-c/g-ccs/g-cit/g-cim/directives/welcome.htm

   b. The Coast Guard Directive System on WWW:
   http://www.uscg.mil/ccs/cit/cim/directives/welcome.htm

   c. An electronic version will also be available via the Coast Guard Marine Safety, Security and Environmental Protection web site:
   http://www.uscg.mil/hq/g-m/index.htm

3. SUMMARY. The revised Chapter 3, Engineering Systems, cancels the existing chapter and provides updated information on electrical and mechanical systems related to the marine safety program. Section A of the revised chapter contains a summary of specific alterations.

DISTRIBUTION – SDL No. 141

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
A																										
B		8	*		5									150	1	1	2									5
C					*							1	*													
D	1	2*		1*	1						1*	*														
E														2	*											
F			1																							
G																										
H																										

NON-STANDARD DISTRIBUTION: (see page 2 and 3)

4. PROCEDURES. Remove and insert the revised Chapter 3 and its table of contents as well as the updated Volume IV table of contents.

5. ENVIRONMENTAL ASPECT AND IMPACT CONSIDERATIONS. Environmental considerations were examined in the development of this directive and have been determined to be not applicable.

6. FORMS/REPORTS. None.

T. H. GILMOUR /s/
Rear Admiral, U.S. Coast Guard
Assistant Commandant for Marine Safety,
Security and Environmental Protection

Non-Standard Distribution:

B:c CCGD8 (14); CCGD7 (11); CCDG13 (9); CCGD9 (8); CCGD5 (7); CCGD1 (6); CCDG11 (5) CCDG14 (4); MLCLANT, MLCPAC (1)

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MARINE SAFETY MANUAL

VOLUME IV

TABLE OF CONTENTS

MARINE SAFETY MANUAL

VOLUME IV

TABLE OF CONTENTS

CHAPTER 3. ENGINEERING SYSTEMS

CONTENTS

CONTENTS

CONTENTS

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CHAPTER 3. ENGINEERING SYSTEMS

A. Introduction.

1. Content and Purpose of the Marine Safety Manual, Vol. IV Chapter 3 (MSM IV CH 3)

a. Purpose. The purpose of the Marine Safety Manuals (MSM) is described in Marine Safety Manual Volume I, Administration and Management, COMDTINST M16000.6 (series), Chapter 1, Section B (available online, see note below). The Marine Safety Manual, Volume IV, Technical, COMDTINST M16000.9 (series), Chapter 3 is intended to provide additional technical information and explanation of Marine Safety engineering systems regulations.

b. Content. The primary content of this chapter is provided to augment Title 46, Code of Federal Regulations (CFR), Subchapters F and J (46 CFR 50-64 and 46 CFR 110-113).

Section A of this chapter, "Engineering Scope and Program Interfaces", provides further detail of the purpose, application and content of this chapter.

Locating the Marine Safety Manuals (MSM) on the Internet: The MSM is accessible through the Internet by first locating the U.S. Coast Guard home page (http://www.uscg.mil/), then select "Marine Safety" under Missions, then "Site Map". Links to the MSM as well as other useful sites including the "G-MSE Office of Design and Engineering Standards" are available there. The Marine Safety Manuals are also available on the USCG Directives System at: http://www.uscg.mil/ccs/cit/cim/directives/welcome.htm.

Locating Navigation and Vessel Inspection Circulars (NVICs) on the Internet: NVICs may be located from the U.S. Coast Guard home page by following the same steps listed above. The direct link is: http://www.uscg.mil/hq/g-m/nvic/index.htm.

2. Overview of Changes to Marine Safety Manual, Volume IV, Technical, COMDTINST M16000.9 (series), Chapter 3 (MSM IV CH 3)

a. Introduction. This revision is a first step in an ongoing project that will be completed in two phases. This phase of the project focuses on areas that are most obviously in need of revision, and can be corrected rapidly. The next phase will be a more detailed revision to add content regarding new systems, and to incorporate the useful information from mechanical and electrical related Navigation and Vessel Inspection Circulars (NVICs).

b. Overview of Changes. Major changes from the previous MSM IV Ch3:

(1) Updated CFR references
(2) Sections re-arranged to coincide with relative location of information in CFR
(3) Deleted obvious outdated information
(4) Changed point of contact information (ex: Commandant (G-MTH) is now Commandant (G-MSE))

3.A.2.b (5) Added "Guide for Electrical Installations on Merchant Vessels and Mobile Offshore Drilling Units", COMDTPUB P16700.4, NVIC 2-89 content to the Electrical Systems section
(6) Removed outdated parts of the Electrical Plan Review section
(7) Deleted Section 3.Q, Nuclear Systems, no longer relevant
(8) Deleted Section 3.D, Regulations and References, outdated information

c. Specific Changes. Cross-Referenced to Old-MSM IV Chapter 3

NOTE: "Previous MSM IV CH3" refers to sections as they existed in the version of MSM IV Chapter 3 that this edition is replacing (publication date unknown, last updated 27 June 1986)

(1) MSM Vol IV, CH 3 Section i, Prologue
  (a) Previous MSM IV Ch3 Sections: N/A, this is a new section
  (b) Alterations: All new content, adapted from MSM Vol II Prologue
(2) MSM Vol IV, CH 3 Section A, Engineering Scope and Program Interfaces
  (a) Previous MSM IV Ch3 Sections: Adapted from previous MSM Vol IV, CH 3, Section A, Engineering Scope and Program Interfaces.
  (b) Alterations:
    i. Updated office designations (ex: Commandant (G-MSE) replaced Commandant (G-MTH-2))
    ii. Updated Commandant (G-MSE-3) responsibilities
(3) MSM Vol IV, CH 3 Section B, Plan Review
  (a) Previous MSM IV Ch3 Sections: Adapted from previous MSM Vol IV, CH 3, Section C, Plan Review of Electrical Systems.
  (b) Alterations:
    i. Added Section 1, Plan Review of Mechanical Systems
    ii. Updated CFR references in Section 2, Plan Review of Electrical Systems
    iii. Removed Table 3-5, List of Electrical Hazard Group Classifications, more current version available in 46 CFR 151.05
(4) MSM Vol IV, CH 3 Section C, Equipment
  (a) Previous MSM IV Ch3 Sections:
    i. MSM Vol IV, CH 3, Section E, Acceptable Equipment.
    ii. MSM Vol IV, CH 3, Section F, Equipment Lists.
    iii. MSM Vol IV, CH 3, Section K, Special Engineering Applications for Pollution Prevention.
    iv. MSM Vol IV, CH 3, Section M, Special Equipment Approvals.
  (b) Alterations:
    i. 3.C.1.a transferred in FAQ from electrical section
    ii. 3.C.1.b changed "need for factory inspections…" to "Coast Guard reserves the right… to conduct factory inspections."
    iii. 3.C.1.b inserted information from Section 2 of NVIC 2-89, Meeting Referenced Standards
    iv. 3.C.1.b (1) updated introduction to correct reference to fuses and hazardous area equipment
    v. 3.C.1.c added CFR reference for independent testing lab

3.A.2.c(4)(b)

- vi. 3.C.2.a and b: stated COMDTINST M16714.3 no longer published in hard copy
- vii. 3.C.2.c Added an example of an equipment approval number
- viii. 3.C.3.a(1) changed title 46 to title 33. Added type III statement.
- ix. Added 3.C.a(5) MSD’s prior to 1/30/76
- x. 3.C.4.a stated that Affidavit system ended and incl ref to applicable FR.
- xi. 3.C.4.b(2) quick disconnect couplings are no longer reviewed by MSE-3
- xii. 3.C.4.c(2) changed IG to 1G and changed tank contents to “heaviest product carried”.

(5) MSM Vol IV, CH 3 Section D, Vessel Inspection Alternatives
- (a) Previous MSM IV Ch3 Sections: This is a new section
- (b) Alterations:
  - i. All new content, will be expanded on in Phase 2 of MSM Vol IV, Ch 3 Update.

(6) MSM Vol IV, CH 3 Section E, Mechanical Systems
- (a) Previous MSM IV Ch3 Sections:
  - i. MSM Vol IV, CH 3, Section J, Engineering Materials
  - ii. MSM Vol IV, CH 3, Section I, Boilers, Pressure Vessels, and Similar Equipment
  - iii. MSM Vol IV, CH 3, Section G, Piping Systems
  - iv. MSM Vol IV, CH 3, Section H, Specific Piping Systems
  - v. MSM Vol IV, CH 3, Section O, Steering Gear
- (b) Alterations:
  - i. Updated responsible offices and their staff symbols.
  - ii. Deleted information no longer relevant.

(7) MSM Vol IV, CH 3 Section F, Automation
- (a) Previous MSM IV Ch3 Sections:
  - i. MSM Vol IV, CH 3, Section L, Automation.
- (b) Alterations:
  - i. Updated to include 46 CFR Part 62
  - ii. Updated incinerator construction requirements
  - iii. Deleted outdated references to 46 CFR Part 63

(8) MSM Vol IV, CH 3 Section G, Electrical Systems
- (a) Previous MSM IV Ch3 Sections:
  - i. MSM Vol IV, CH 3, Section B, Overview of Electrical Systems.
- (b) Alterations:
  - i. Inserted majority of NVIC 2-89, with some modifications. Major alterations to NVIC 2-89 content inserted:
    - a. Altered order of topics covered to correspond with Subchapter J
    - b. Corrected or removed outdated references
    - c. Deleted information superseded by recent CFR changes
    - d. Moved Section 2 of NVIC 2-89, ‘Referenced Standards and Equipment Required to be Listed or Labeled’ to Equipment section of MSM (3.C.1)
    - e. Revised Hazardous Location guidance, (NVIC 2-89 Section 7, MSM 3.G.6.d) to highlight differences between zonal and divisional classifications of hazardous areas

3.A.2.c(8)(b)i.

f. Revised Wire and Cable guidance (NVIC 2-89 Section 8, MSM 3.G.14.b) reflecting alterations to 46 CFR 111.60, clarifying UL listing of shipboard cable, and providing additional guidance for MIL-C-915 cables

g. Revised Components and Equipment guidance (NVIC 2-89 Section 9, MSM 3.G.16.a), clarified that regulations of this part do not apply to aids to navigation

ii. Added table 3G-1, Applicable Electrical Regulations

iii. Added new section on Gel Cell Batteries (3.G.6.c) to provide a brief description of new equipment that may be encountered

iv. Added guidance regarding use of emergency generator to 3.G.19.a based on IACS and SOLAS determinations

v. Added guidance regarding emergency loads to 3.G.19.c based on public question

vi. Added alarm signal sound pressure level guidance to 3.G.20.d, provided distances based on public question

(9) MSM Vol IV, CH 3 Section H, Novel Vessel Designs

(a) Previous MSM IV Ch3 Sections:

i. MSM Vol IV, CH 3, Section N, Novel Vessel Designs.

ii. MSM Vol IV, CH 3, Section P, Deepwater Ports.

(b) Alterations:

i. Updated office designations (ex: Commandant (G-MSE-3) replaced Commandant (G-MTH-2)).

d. The Future of MSM IV Ch3. The second phase of the MSM Vol IV, Ch3 revision will include a more detailed review and update of the existing text, as well as the addition of new topics. Phase two changes will likely include:

(1) Changing the format to that used by the Marine Safety Manual Volume II, Material Inspection, COMDTINST M16000.7A (series)

(2) Update to reflect latest regulations and policy.

(3) Guidance for new vessel types such as FPSOs.

(4) Descriptions and explanations of new technologies inspectors may encounter, such as cycloconverters and fuel cells.

(5) Insertion of the useful information contained in the electrical and mechanical NVICs, the same approach as used with “Guide for Electrical Installations on Merchant Vessels and Mobile Offshore Drilling Units”, COMDTPUB P16700.4, NVIC 2-89 in this revision. These NVICs include:

1-69, Automated Main and Auxiliary Machinery
1-71, Repair of Boiler Safety Valves
2-71, Pipe Stress Analysis Calculations; Procedure for Submission of
4-71, Valves Employing Resilient Material
7-73, Main Propulsion Boiler Automation
7-74, Oil-Water Separators; Acceptance of
1-78, Automation of Offshore Supply Vessels of 100 Gross Tons and Over
2-79, Aluminum Bus Bars
1-81, Guidance for Enforcement of the Requirements of the Port and Tanker Safety Act of 1978(PTSA) Pertaining to SBT,

3.A.2.d(5) 1-81, (cont'd) CBT, COW, IGS, Steering Gear, and Navigation Equipment for Tank Vessels
9-82, MSD Certification
13-83, Coast Guard Retention of Commercial Vessel Plan Review Case Files
4-84, Equivalent Determination for Existing, Installed Oil-Water Separators which have Not Received U.S. Coast Guard Approval
6-84, Automated Main and Auxiliary Machinery; Supplemental Guidance On
8-84, Recommendations for the Submittal of Merchant Vessel Plans and Specifications
9-84, Electrical Installations in Agricultural Dust Locations
11-86, Guidelines Governing the Use of Fiberglass Pipe (FGP) on Inspected Vessels
5-89, Guidelines for Nondestructive Testing of Pressure Vessel Type Cargo Tanks Aboard Tank Barges
10-92, Coast Guard Recognition of Registered Professional Engineer Certification of Compliance with Coast Guard Requirements
11-92, Guidance for Acceptance of the National Board of Boiler and Pressure Vessel Inspectors (NBBI) National Board Inspection Code (NBIC) for Repairs and Alterations to Boilers and Pressure Vessels
5-93, Guidance for Certification of Passenger Carrying Submersibles

e. Providing Input. Requests or recommendations, or even recommended text from Coast Guard field units regarding the phase two changes would be greatly appreciated and given full consideration. All levels of the "M" Program are encouraged to participate in making the MSM a better tool for the M Community—Coast Guard, industry, and the general public.

To provide input via e-mail on the Coast Guard SWIII:
Open the Global Address List
Select “Lst-G-MSE-3”, e-mail to any person on that list or to the whole division.

To provide input via e-mail from outside the Coast Guard Data Network:
(1) Indicate “MSM Comment” in the title and send to lst-g-msm-3@comdt.uscg.mil

To mail input, send to:
U.S. Coast Guard
Systems Engineering Division, Commandant (G-MSE-3), Room 1308
2100 Second St., S.W.
Washington, DC 20593-0001

3. Scope. The contents of this chapter are directly related to the responsibilities of the Systems Engineering Division, Commandant (G-MSE-3). This division is responsible for marine and electrical engineering, and certain equipment approvals. The functions of Commandant (G-MSE-3) are to:

3.A.3 a. Engineering Services. Provide engineering service to the Marine Safety Center (MSC), and marine safety offices (MSO's), other divisions within the Office of Design and Engineering Standards, Commandant (G-MSE), and offices at Coast Guard Headquarters.

(1) Regulations. Develop and maintain regulations that promote the protection of life at sea, property, and the marine environment to the extent permitted and required by law in the areas of marine and electrical engineering. Initiate and guide research to support existing or envisioned engineering regulations, taking into account the need to keep abreast of advancing technology in materials, fabrication, and equipment.

(2) Application. Provide technical advice and guidelines to Coast Guard offices in the application of the Marine Safety Manual and Navigation and Vessel Inspection Circulars (NVIC's).

(3) Committees. Participate actively in national technical committees and societies such as the American Society of Mechanical Engineers (ASME), American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM), Society of Naval Architects and Marine Engineers (SNAME), National Electrical Manufacturers Association (NEMA), and Institute of Electrical and Electronic Engineers (IEEE).

(4) International. Participate actively in international technical organizations such as the International Maritime Organization (IMO), the International Electrotechnical Committee (IEC), and the International Organization for Standardization (ISO).

(5) Liaison. Maintain close liaison with other government agencies, and classification societies such as the American Bureau of Shipping (ABS), Det Norske Veritas (DNV), Lloyd's Register of Shipping (LR), and Germanischer Lloyd (GL).

(6) Evaluation. Evaluate proposals from shipbuilders, design agents, engineers, and equipment manufacturers concerning systems and equipment that do not meet the regulations, but which may provide equivalent protection to life, property, and the environment.

(7) Approvals. Review and approve the design and construction details of boilers and certain components for piping and electrical systems.

(8) Investigation. Assist the Office of Investigations and Analysis, Commandant (G-MOA), in the review of marine casualty investigations that result from failure involving an aspect of marine or electrical engineering.

b. Interfaces. In the accomplishment of their daily tasks, members of Commandant (G-MSE-3) must interact with personnel both inside and outside the Coast Guard. The sections below summarize some of the more common contacts:

(1) At Coast Guard Headquarters. The Systems Engineering Division provides technical support services to other divisions of the

3.A.3.b (1) (cont'd) Commandant (G-MSE). These services consist primarily of evaluating installations for new and existing merchant vessels, reviewing repair procedures, assessing casualties, and reviewing and monitoring regulation and research and development projects. Commandant (G-MSE-3) works closely with the Office of Compliance, Commandant (G-MOC), in areas of equipment approval, installation and repair; with the Office of Investigations and Analysis, Commandant (G-MOA), in casualty assessment and National Transportation Safety Board (NTSB) responses as well as in matters relating to manning of automated engine rooms. In many instances, responses to industry are the result of efforts of two or more divisions.

(2) With Field Units. The Systems Engineering Division provides technical services to the Marine Safety Center (MSC) through the development of regulations, development of policy, evaluation of new developments, and evaluation of inquiries and appeals in the machinery and electrical areas. Commandant (G-MSE-3) also provides technical services to field inspection offices throughout the country as requested.

(3) With Commandant (G-LRA) and Commandant (G-MSR). The Systems Engineering Division normally has several regulatory projects underway at any given time. For each of these regulatory projects, the division provides a project manager who works with the project attorney from the staff of the Office of Regulations and Administration, Commandant (G-LRA), and the Office of Standards Development, Commandant (G-MSR), to produce a completed regulation package. This requires close liaison between the division and Commandant (G-LRA) and Commandant (G-MSR), from formulation of the work plan, through notice and public comment periods, to publication of Final Rules.

B. Plan Review.

1. Plan Review of Mechanical Systems.

a. Introduction. Plan review and approval of individual vessels falls under the cognizance of the Coast Guard's Marine Safety Center (MSC). Marine Safety Center guidance regarding mechanical system plan review may be found online at: http://www.uscg.mil/hq/msc/index.htm. If this Internet address is no longer valid the MSC web page can be located by first going to the U.S. Coast Guard home page (http://www.uscg.mil/) and completing a search for the "Marine Safety Center".

2. Plan Review of Electrical Systems.

a. Introduction.

(1) Objectives. Plan review is performed to ensure that the electrical arrangement, materials, and installation as shown on the plans comply with the applicable laws and regulations for the vessel or unit. The primary purposes of the electrical requirements are to arrive at adequate and reliable shipboard electrical systems, the components of which provide safety to personnel from electrical shock, and to minimize the danger of

3.B.2.a (1) (cont'd) fire originating from within the electrical system. After the initial certification of a vessel or unit by the Coast Guard, subsequent plan review may be required due to electrical repairs or alterations affecting the safety of the vessel, its equipment, and crew. If considered necessary by the officer in charge, marine inspection (OCMI), drawings must be approved before work is started. Repairs to existing installations must meet the regulations in effect on the date of the original installation or the regulations in effect on the date of the repair.

(2) General Procedures. Guidance listed in section 3.B.1.a above also applies for finding electrical system plan review guidance online.

Prior to a vessel's construction, plans such as those listed in 46 CFR 177.05 for small passenger vessels, and in 46 CFR 110.25 are reviewed. The plans listed in those sections are general in character, but include all plans that normally show construction and safety features coming under the cognizance of the Coast Guard. In the case of a particular vessel, all of the plans enumerated may not be applicable; it is intended that only those plans and specifications be submitted as will clearly show the vessel's arrangement, construction, and required equipment. Because the regulations give only a general listing of the plans and specifications that require review by the Coast Guard, "Recommendations for the Submittal of Merchant Vessel Plans and Specifications", COMDTPUB P16700.4, NVIC 8-84, was published to provide further clarification. This circular is a detailed guide on recommended plan submittal procedures. Some of the plans and specifications required by the Coast Guard are also necessary for the approval of construction by the American Bureau of Shipping (ABS) for vessels classed by that organization. In this regard, "Acceptance of Plan Review and Inspection Tasks Performed by the American Bureau of Shipping for New Construction or Major Modifications of U.S. Flag Vessels", COMDTPUB P16700.4, NVIC 10-82, CH-2, was published to provide information on ABS plan approval procedures intended to facilitate industry activities and reduce duplication of effort between the ABS and the Coast Guard.

(3) Handling of “Existing” Vessels. The regulations do not include requirements for vessels existing before the effective date of the regulation. Persons must refer to the regulations in effect for older existing vessels in order to determine construction requirements for those vessels.

b. Plan Review Guidance.

(1) Introduction. The intent of this section is to provide:

(a) Check-off lists for review of typical electrical plans;

(b) A reference for technical data, formulas, and principles used in routine plan review;

3.B.2.b(1) (c) Some items of policy; and

(d) An index for detailed reference information not contained in this guide or regulations.

This section is intended as a guide for the plan reviewer, and should not be considered as containing hard-and-fast requirements. The user's discretion should be applied during its application.

(2) One-Line Diagram Reference Drawing. The one-line diagram reference drawing, Figure 3-1, and the attached index, Figure 3-2, are provided as a directory to applicable regulations. This diagram is purely hypothetical. The item number on the diagram may be cross-referenced to the index to find a listing of applicable regulations. [NOTE: Unless otherwise indicated in Figure 3-2, references are to Title 46 CFR, as in "111.12."]

FIGURE 3-1
ELECTRICAL PLAN REVIEW GUIDE
TYPICAL ONE-LINE DIAGRAM

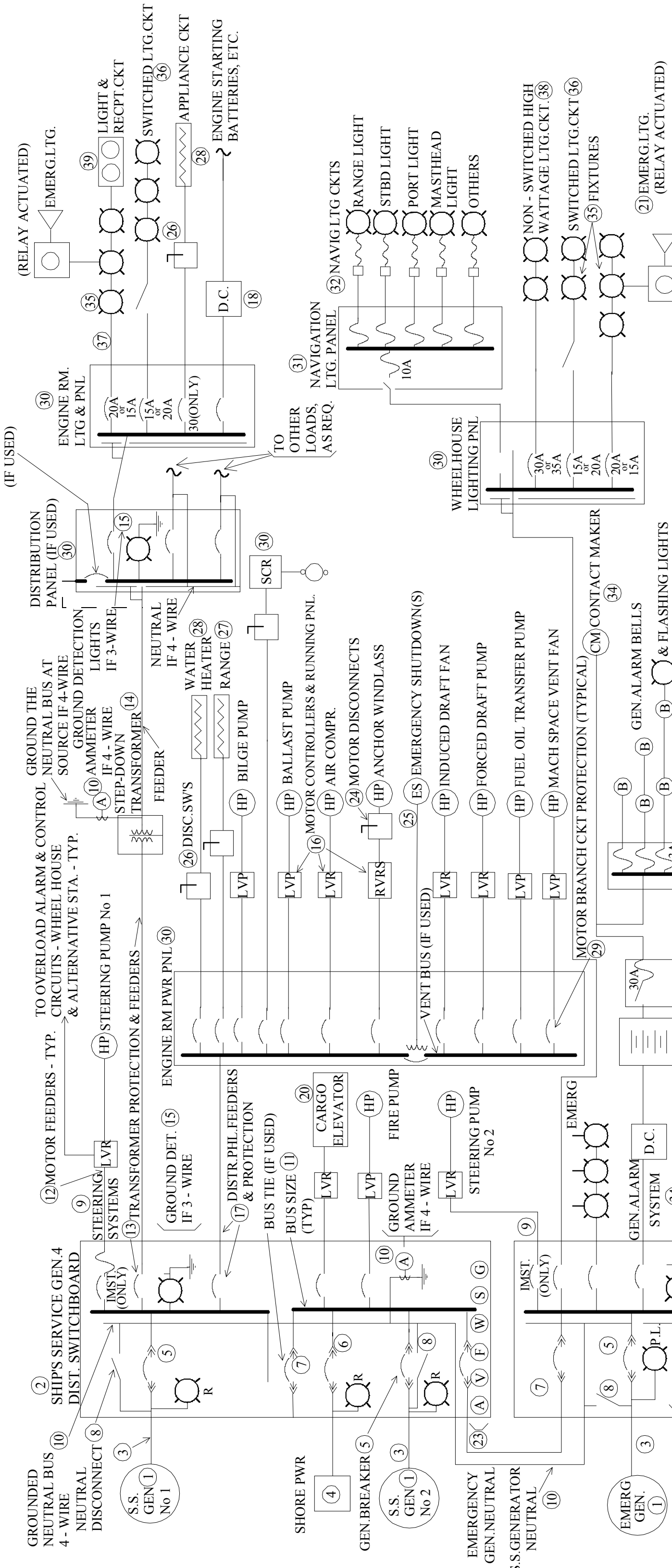


FIGURE 3-2

INDEX FOR REFERENCE DRAWING TO TITLE 46 CFR, NATIONAL ELECTRICAL CODE (NEC), INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE) STD. 45-1983, UNDERWRITERS LABORATORIES (UL), ETC.

ITEM	TITLE	REFERENCE*	SPECIFIC AREAS
1	Generators	111.12 112.50 111.12-7, -11	Ship's service Emergency Parallel operation
2	Generator & Distribution Switchboards	111.30	General
3	Generator Cables	111.60-3 111.60-7 111.60-5 & 111.12-9	Application Demand load Installation
4	Shore Ties & Connection Boxes	111.83	Construction
5	Generator Circuit Breakers	111.30-25 111.50-7 111.50-5(a) 111.12-11 111.54-1(a)(3)	Switchboard-mounted Enclosures Location Circuits & Protection Interrupting capacity
6	Shore Tie Circuit Breakers	111.30-25 111.50-5(a)(2) 111.54-1(a)(3)	Switchboard-mounted Switchboard-mounted Interrupting capacity
7	Bus Tie Circuit Breakers	111.60-7	Demand load
8	Generator Neutral Disconnects or Links	111.30-25(b)	Switchboard-mounted
9	Steering Systems	58.25 33 CFR 164.39	Steering apparatus Foreign tank vessels
10	Generator Neutral Grounding	111.05-17	Ship's service and emergency generator
11	Bus Sizes	IEEE STD 45-1983	Table A-27 & 111.30-19
12	Motor Feeders	111.60-7	

FIGURE 3-2 (cont'd)

ITEM	TITLE	REFERENCE*	SPECIFIC AREAS
13	Transformers, Feeders, and Protection	MSM Subparagraph 3.G.5	
14	Transformers, General	111.20	
15	Ground Detection	111.30-20(e)(1) 111.30-27(e) 111.05	
16	Motor Controllers	NEC 430-86 111.70-3(a) 111.70-3(b)&(c)	Location Enclosures Low voltage protection (LVP) and low voltage release (LVR) types
17	Distribution Panel Feeders	111.60-7 111.54-1(a)(3) 111.51	Demand loads Interrupting rating Selective operation
18	Battery Chargers	111.15-30 111.15-25	 Reverse current protection
19	Storage Batteries	111.15-1 111.15-5 111.15-10 111.15-5(f)-(g) 111.15-20 112.55	General Installation and arrangement Ventilation Corrosion protection Conductors Emergency power and lighting systems
20	Electric Elevators & Dumb Waiters	ANSI A17.1 & A17.1 111.91	Safety Code
21	Emergency Lights & loads	112.43 112.01-10 112.15	Emergency lighting systems Automatic systems Emergency loads
22	Signaling Lights	111.75-18	
23	Switchboard Instrumentation & Control Equipment Required	111.30-25	AC switchboards ship's service and emergency

FIGURE 3-2 (cont'd)

ITEM	TITLE	REFERENCE*	SPECIFIC AREAS
24	Disconnects (Motors)	111.70-1	
25	Emergency Shut Down	111.103	
26	Disconnects (Switching Means)	111.55	
27	Appliances	111.60-7 111.77	Demand loads Standard
28	Motor Circuit Protection	111.70-1	
29	Distribution Panelboards	111.40 111.50-5,-7	
30	Navigation Light Indicator Panels	111.75-17	
31	Semiconductor-Controlled Rectifier (SCR) Circuits	111.33	Electric propulsion
32	General Alarm Systems	113.25	
33	Lighting Fixtures	111.75-20 UL 1598A 111.05-3	Marine type Construction Grounding
34	15- or 20-Ampere Lighting Branch Circuits	111.75-5(e)	"Switched" lights and receptacles
35	Receptacle Circuits	111.79-1 111.05-3 UL 498 111.81	General Grounding Attachment plugs and receptacles Outlet boxes and fittings Cabinets and boxes

3.B.2.b (3) Operating Load Factors.

(a) Tables.

i. Sample Load Analysis (Figure 3-3).

ii. Typical Operating Load Factors (Figure 3-4).

(b) References.

i. U.S. Navy Design Data Sheet, DDS 310-1, "Design Details of Generating Plants."

ii. SNAME T & R Bulletin 3-11, "Marine Steam Power Plant Heat Balance Practices," Section 3.2.15.

iii. Marine Engineering, Harrington, 1971, pp. 607-609.

iv. NVIC 8-84, section 28.d.(1) (see paragraph 3.L.2 below).

(c) General Requirements. Ship's service generating plants must be sized for the anticipated operating load as required by 46 CFR 111.10-4. Emergency generators shall be sized to supply all loads simultaneously connected to it as required by 46 CFR 112.05-5. To determine if the generators are adequate, a load analysis is necessary and is required to be submitted for review by 46 CFR 110.25-1(b). Demand factors (d.f.) are essential to the load analysis but often can vary, as can be seen from the typical values in Figure 3-4. The individual characteristics of the vessel should be considered in the determination of demand factors. The review of the load analysis should determine if the:

i. Individual load factors used are reasonable.

ii. Application of the load factors is reasonable and thorough.

iii. Generating plant is adequate and in accordance with the applicable regulations.

(d) Considerations.

i. Loads can be classified by various operating conditions such as port, anchor, sea, functional, emergency, maneuvering, or cold start. For the purpose of plan review, only the normal sea load, maneuvering load and emergency load are considered, unless special considerations for the safety of the ship require otherwise (e.g., at sea cargo transfer (functional)).

ii. A motor may be oversized for its attached load and thus not operate at its rated capacity.

FIGURE 3-3
SAMPLE LOAD ANALYSIS

NOTE: All figures used are purely hypothetical.

DISTRIBUTION A	ATTACHED LOAD	DEMAND FACTOR	DEMAD LOAD	
Bilge Pump	5 KW	0	0	
Ballast Pump	10 KW	0.1	1	KW
A/C - Heater	10/20 KW	0.8	8/16	KW*
Cargo Circ. Pump	15 KW	0.6	9	KW
	Dist. A Total 0 + 1 + 16 + 9	=	26	KW

DISTRIBUTION B				
Steering Pump #1	10 KW	0.9	9	KW
Steering Pump #2	10 KW	0	0	**
Steering Control	1 KW	0.9	.9	KW
Bow Thruster	40 KW	0.4	16	KW
	Dist. B Total 9 + 0 + .9 + 1	=	25.9	KW

DISTRIBUTION C				
Main Deck Ltg. Fwd.	4 KW	0.5 ***	4	KW
Main Deck Ltg. Aft	4 KW	0.5		
Eng. Rm. Ltg. Port	2 KW	0.9 ***	3.6	KW
Eng. Rm. Ltg. Stbd.	2 KW	0.9		
	Dist. C Total 4 + 3.6 =		7.6	KW

DISTRIBUTION D				
Range	12 KW	0.4	4.8	KW
Water Heater	15 KW	0.6	9.0	KW
	Dist. D Total	4.8 + 9.0 =	13.8	KW

TRANSFORMER #1			
Dist. C	7.6 KW	1.0 @	.95
Dist. D	13.8 KW	Efficiency	****
Transformer 1 Total is 1.05 (1.0)(7.6 + 13.8)		= 26.9	KW

MAIN SWBD		
Dist. A	26	KW
Dist. B	25.9	KW
Transformer #1	26.9	KW
Generator Demand load	78.8	KW
Full load Gen. Capacity	85	KW

* Relationship exists, take larger load.
** One pump is the standby.

*** Similar loads given group factor.
*** Reduced efficiency increases demand load. typ. transformer eff .96-.99

FIGURE 3-4

TYPICAL OPERATING LOAD FACTORS

LOAD DESCRIPTION	NAVY FACTORS		MAR. ENG. FACTORS		SNAME
	Sea	Emerg	Sea	Emerg	Sea
Main Steering Gear Pump	0.3	0.3	0.1		0.2
Stby. Steering gear pump	0	0			
Steering gear servo. Pump	0.5	0.5			
Steering control	0.5	0.5	0.1		
Steering aux. Heater	0	0			
Shaft turning gear	0	0			
Stern tube bearing lube oil pump			0.5		
Main cond. Pump	0.9	0	0.4		0.75
Main circ. Pump	0.9	0	1.0		0.9
Aux. cond. Pump					0.9
Aux. circ. pump	0.6	0			0.9
Main feed pump					0.8
Main feed boost pump	0.9	0.5			
Emer. feed boost & transfer pump	0	0			0
Reserve feed transfer pump	0.2	0			0.5
Aux. condenser condensate pump			0		
Atm. Clean drain tank pump			0.6		
L.P. heater drain pump					0.65
L.P. steam gen. Feed pump			0.9		
Aux. boiler	0	0			
Main turb. gland exhauster	0.9	0	0.9		0.9
Aux. turb. gland exhauster	0.5	0			
F.W. Drain coll. Tank pump	0.6	0			0.6
Main L.O. purifier	0.3	0	0.9		0.35
Main feed L.O. pump	0.9	0	0.9	0.3	0.9
Stby. L.O. serv. pump	0	0.2		1.0	
L.O. transfer pump	0.1	0			0
L.O. cooler circ. pump					0.9
L.O. heater					0.1
F.O. service pump	0.9	0	0.4		0.85
F.O. transfer pump	0.1	0	0.1		0.1
F.O. stripping pump	0	0			
F.O. stripping drain and transfer pump	0.3	0			
Red. gear L.O. stby. pump	0	0			
Prop. hyd. stby. pump	0	0			
Elec. prop. exciter	0.9	0			
Elec. prop. equip. heater	0	0			
Prop. motor vent fan	0.9	0			
Prop. motor L.O. service pump	0.9	0			
T/G circ. pump	0.5	0			

FIGURE 3-4 (Continued)

LOAD DESCRIPTION	NAVY FACTORS		MAR. ENG. FACTORS		SNAME
	Sea	Emerg	Sea	Emerg	Sea
T/G cond. Pump	0.5	0			
T/G start L.O. pump	0	0.9		0.9	
Sea valves	0	0			
Emer. gen. S.W. booster	0	0.9			
S.W. boost pump	0.3	0			
Air preheater					0.9
S.W. service pump	0.1	0	0.6		0.8
Bilge and fuel stripping pump	0.1	0	0.1		
Bilge pump	0.1	0	0.1		0.1
Flushing pump	0.1	0			0.4
Fire pump	0.2	0.4	0		0
Bilge & ballast priming pump		0	0.1		
Fire and bilge pump					0
Fire and general service pump			0		
Bilge and ballast pump					0.2
Ballast pump					0.2
Fog/Foam sys. Pump	0		0		
Forced draft blower			0.5		
H.W. circ. Pump	0.6	0	0.1		0.7
H.W. heater	0.5	0.1			0.5
Cargo stripping pump	0	0			
Liquid Cargo transfer pump	0	0	0		0
Cargo brine circ. pump			0.7		
Cargo air coolers			0.9		
Cargo dehumidifier					0.5
Window defrosters and wipers	0	0			
Generator space heaters	0	0		1.0	
Anchor windlass	0	0			
Capstan	0	0			
Personnel elevators	0.2	0			
Cranes	0	0			
Cargo elevators	0	0			
Shop tools	0.1	0	0.1		0.1
Welder	0.1	0			
Test board	0.1	0	0	0	0.2
Battery charger	0.2	0			0.2
I.C. battery charger				1.0	
Ventilation	0.9	0.4	0.9		0.85
Duct & space heaters	0.4	0			0.4
Deck mach. Heaters					1.0
I.C. system	0.4	0.4		1.0	0.4
Radar	0.5	0.5		1.0	
Gyro				0.5	0.4

FIGURE 3-4 (Continued)

LOAD DESCRIPTION	NAVY FACTORS		MAR. ENG. FACTORS		SNAME
	Sea	Emerg	Sea	Emerg	Sea
Radio	0.4	0.4			
Searchlights	0	0			
Mach. space ltg.	0.9	0.9			0.9
General ltg.	0.6	0.4	0.4		0.6
Emergency ltg.	0.6	0.4		0.9	
Navigation ltg.	0.6	0.2		0.4	0.5
Service area ltg			0.4		0.35
SS. reefer circ. pump					0.4
SS. reefer compressor	0.3	0	0.1		0.4
Cargo reefer cmp.	0.3	0	0.6		
A.C. compressor	0.7	0.4	0.8		0.75
A.C. chill wtr. pump	0.7	0.4	0.9		0.75
A.C. S.W. circ. pump	0.7	0.4			0.75
A.C. fan					0.75
A.C. H.W. circ. pump			0.6		0.75
Unit coolers	0.2	0			
Oven/range	0.4	0			
Galley equip.	0.3	0			0.3
Refrig/freezer	0.5	0			
Refrig. small	0.3				0.3
Pantry equip.	0.2	0			0.3
Laundry equip.	0.2	0			0.2
Hospital equip.	0.1	0.1			0.2
Electronics	0.5	0.2	0.5		0.45
Distiller plant	0.7	0			
Distiller brine ovbd.			0.8		0.75
Distiller cond. pump			0.3		0.6
Distiller feed pump			0.8		0.75
F.W. transfer pump			0		
Ice water circ. pump			1.0		0.7
Potable water pump	0.3		0.2		
Drinking fountain	0.4				
H.P. air compressor	0.1				
S.S. air compressor	0.1		0.1		0.3
Control air compressor	0.6		0.2		0.4
Sewage pump	0.1		1.0		0.2
Sewage macerator	0.1		1.0		
Sewage blower			1.0		
Cathodic protection			0.7		
Ice water circ. pump			1.0		0.7
Brine circ. pump			1.0		
Reefer container recept.			0.9		
Winches					
Bow thruster					
Main control console			0.6		
Boiler console			0.6		
R.A.I., E.O.T., alarms			1.0		

3.B.2.b(3)(d)

iii. Reference (ii) provides formulas for the determination of load factors for major steam propulsion vessels.

iv. Load factors for individual loads, in general:

$$\text{Load factor} = \frac{\text{Operating bhp}}{\text{Rated bhp}} \times \frac{\text{No. hours operation}}{\text{24 hours}}$$

or

$$\text{Load factor} = \frac{\text{Operating KW}}{\text{Rated KW}} \times \frac{\text{No. hours operation}}{\text{24 hours}}$$

Often, operating load information is not provided and load factors become $\frac{\text{No. hours operation}}{\text{24 hours}}$

v. A single load factor for group loads may be assigned if they meet one of the following criteria.

a. Two or more loads operate with a definite relationship to each other (e.g., heating and air conditioning);

b. When the relationship described in (a) above is not clear, but is known to exist (e.g., galley equipment);

c. When low power loads in the same space can be assigned roughly the same load factors (e.g., radios and electronics).

vi. Known load use data should always be used in lieu of demand factors, if available.

vii. Power conversions and their efficiency should be considered (e.g. power factors, transformers, semiconductor controlled rectifiers (SCR's). Due to efficiency below 1.0, apparent connected loads may be increased due to the conversion equipment).

viii. Loads that are provided individual factors in the analysis should not be additionally assigned a group factor, and vice versa (e.g., 0.3 (individual factor) x 0.4 (group factor) =0.12 (final factor) (either 0.3 or 0.4 could be used, but not 0.12)).

ix. Factors of zero (0) are assigned to equipment that is seldom used.

x. Factors of 0.9 and 1.0 are used where motors operate at full load for an extended period of time.

xi. Standby units, or duplicate units, should be listed and assigned a factor of zero unless it is continuously idling. The primary unit should be assigned an

3.B.2.b(3)(d)

xi. (cont'd) appropriate factor, e.g., Steering pump No. 1, d.f. 0.9; Steering pump No. 2, d.f. = 0.0 (Stby).

xii. The development of standard load factors for given classes of vessels is encouraged, as time and experience permit.

xiii. Large equipment-unusually large loads, as compared to the generating capacity-should be assigned appropriate factors assuming that other non-essential loads are not operated simultaneously.

xiv. As a final check on the adequacy of a load analysis, check to see that the generating plant is adequate to simultaneously carry the loads vital to the survival of the vessel in an emergency such as fire or flooding. These loads should include:

a. Steering;

b. Vital propulsion auxiliaries;

c. Ventilation;

d. Communications;

e. Fire pumps;

f. Alarms;

g. Bilge pumps;

h. Emergency lighting;

i. Radar; and

j. Controls.

xv. For unmanned machinery spaces, remotely operated emergency loads, such as bridge started fire pump, should be assigned a load factor of 1.0.

xvi. Automatically started equipment should be provided a load factor of 1.0 without regard for spinning reserve.

xvii. Special functional operations of the vessel, such as underway replenishment (a Military Sealift Command (MSC) ship), dredging (a hopper dredge), and at-rig offloading (an offshore supply vessel) do not require one generator in reserve. Normal at sea operations such as cargo cooling (refrig. ship) and liquid cargo recirculation (offshore supply vessels) do require one generator in reserve.

3.B.2.b (4) Power And Lighting Transformers.

(a) References.

i.	46 CFR 111.20	Transformers
ii.	46 CFR 111.20-15	Transformer Feeder Circuits
iii.	46 CFR 111.05	Grounding
iv.	NVIC 2-79	"Aluminum Bus Bars"

(b) General Considerations.

i. Transformers should be suitably constructed for the intended use, considering materials and insulation. Aluminum-wound transformers should be factory constructed and fully encapsulated, and all connections should be made in accordance with NVIC 2-79.

ii. Overcurrent and short circuit protection must be provided for primary and secondary windings and feeder cables in accordance with the National Electrical Code (NEC) Article 450. The turns ratio should be considered in calculating full load currents.

iii. Secondary circuits should be provided with a ground detection circuit (see 46 CFR 111.05-21).

iv. Secondary circuit neutral conductors should be grounded.

v. Auto transformers are not to be used for power and lighting circuits.

(c) Power And Lighting transformer Check-off List.

i. Suitable construction.

ii. Secondary provided ground detection.

iii. Secondary neutral grounded (as applicable).

iv. Overcurrent protection provided and limits currents as per NEC Article 450.

v. Connections to aluminum wound transformers made in accordance with NVIC 2-79 if factory-installed terminations are not suitable for connecting to copper conductors.

(5) Semiconductor Controlled Rectifiers (SCR).

(a) References.

i. 46 CFR 111.33.

3.B.2.b(5)(a)

ii. ABS Rules For Building And Classing Steel Vessels, Part IV Ch 8.

(b) SCR System Check-Off List.

i. Meets the requirements of 46 CFR 111.33, and for a switchboard and/or electric propulsion installation, 46 CFR 111.30.

ii. Name plate data.

iii. Heat removal system.

iv. Cooling.

v. Immersed type with non-flammable liquid and no leakage with vessel inclined.

vi. Located away from heat sources.

vii. Temperature rating and operating range.

viii. Unrestricted air circulation if naturally cooled.

ix. Inlet air temperature within design limits.

x. Loss of cooling shutdown.

xi. Inlet cooling water temperature.

xii. Watertight or dripproof rectifier stack.

xiii. Vent exhaust does not terminate in a hazardous area.

xiv. Vent exhaust does not impinge on electrical equipment in enclosure.

xv. High temperature alarm or shutdown.

xvi. SCR propulsion systems:

a. Meet ABS Sections 4-8-5/5.17.9 and 4-8-5/5.17.10.

b. Current and current rate limiting circuit.

c. Overcurrent protection.

d. High temperature alarm set below shutdown temperature.

e. Internal overcurrent device coordination.

f. Blown fuse detection system.

g. In dry place.

3.B.2.b(5)(b) xvii. SCR motor control:

a. Overspeed trip; loss of field (shunt).

b. Shunt motor field excitation interlock.

(6) Electrical Installations In Hazardous Locations.

(a) Tables and Diagrams.

i. NEC Table 500-8(b) – Temperature Markings (Figure 3-5).

ii. Tankship and Tank Barge Weather Deck Criteria (Figure 3-6).

iii. Specified Hazardous Locations (Figure 3-7).

iv. Summary of Minimum Requirements for Carriage of Bulk Dangerous Cargoes on Unmanned Tank Barges (Figure 3-8).

v. Recommended Plan Review Checkoff for Hazardous Locations (Figure 3-9).

FIGURE 3-5

TEMPERATURE MARKINGS
NEC ART. 500 – TABLE 500-8(b)

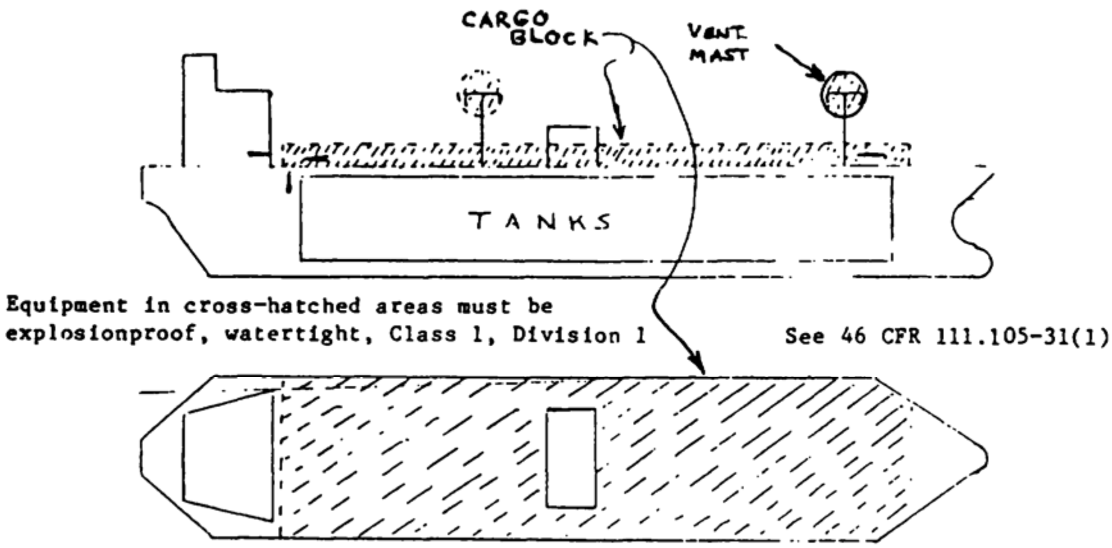
MAX. TEMP. °C	°F	MARKING
450	842	T 1
300	572	T 2
280	536	T 2 A
260	500	T 2 B
230	446	T 2 C
215	419	T 2 D
200	392	T 3
180	356	T 3 A
165	329	T 3 B
160	320	T 3 C
135	275	T 4
120	248	T 4 A
100	212	T 5 *
85	185	T 6 *

Marking shall not exceed auto ignition temp. of the atmosphere encountered.

* Non-heat producing equipment, and that with a temp. of 100°C or less, need not be marked.

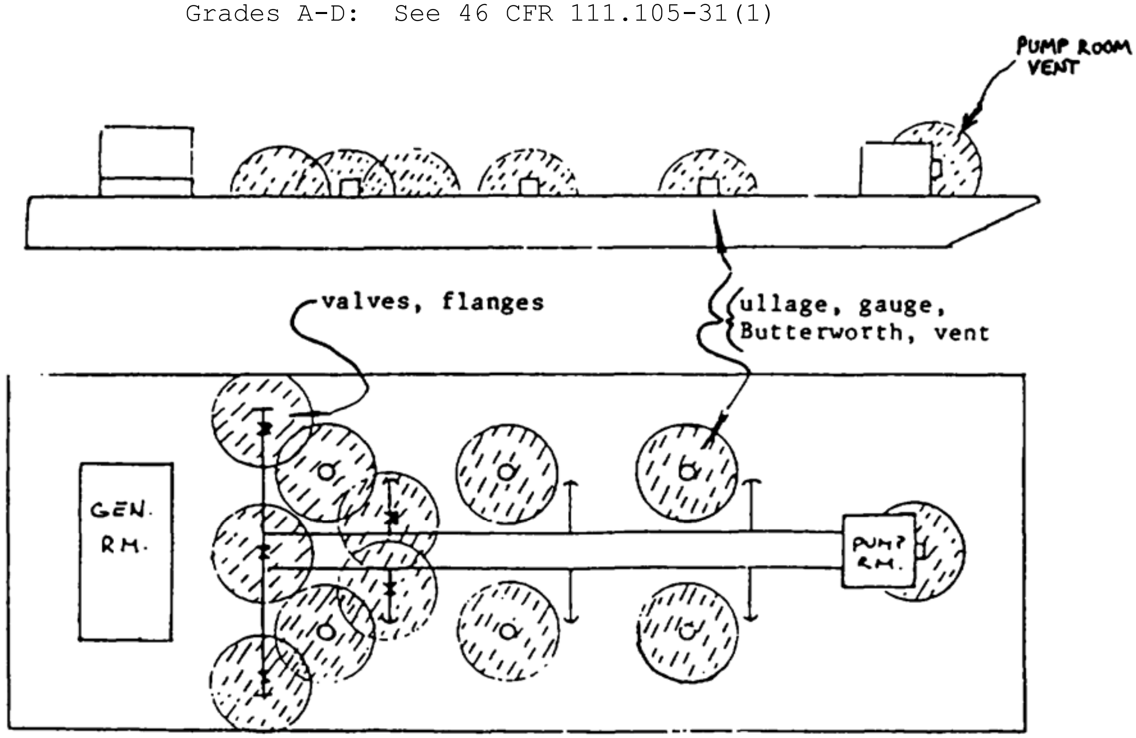
FIGURE 3-6

TANKSHIP WEATHERDECK CRITERIA



TANK BARGE WEATHERDECK CRITERIA

Grades A-D: See 46 CFR 111.105-31(1)



10-foot rule: Equipment in cross-hatched areas must be explosion proof, watertight Class 1, Division 1

FIGURE 3-7

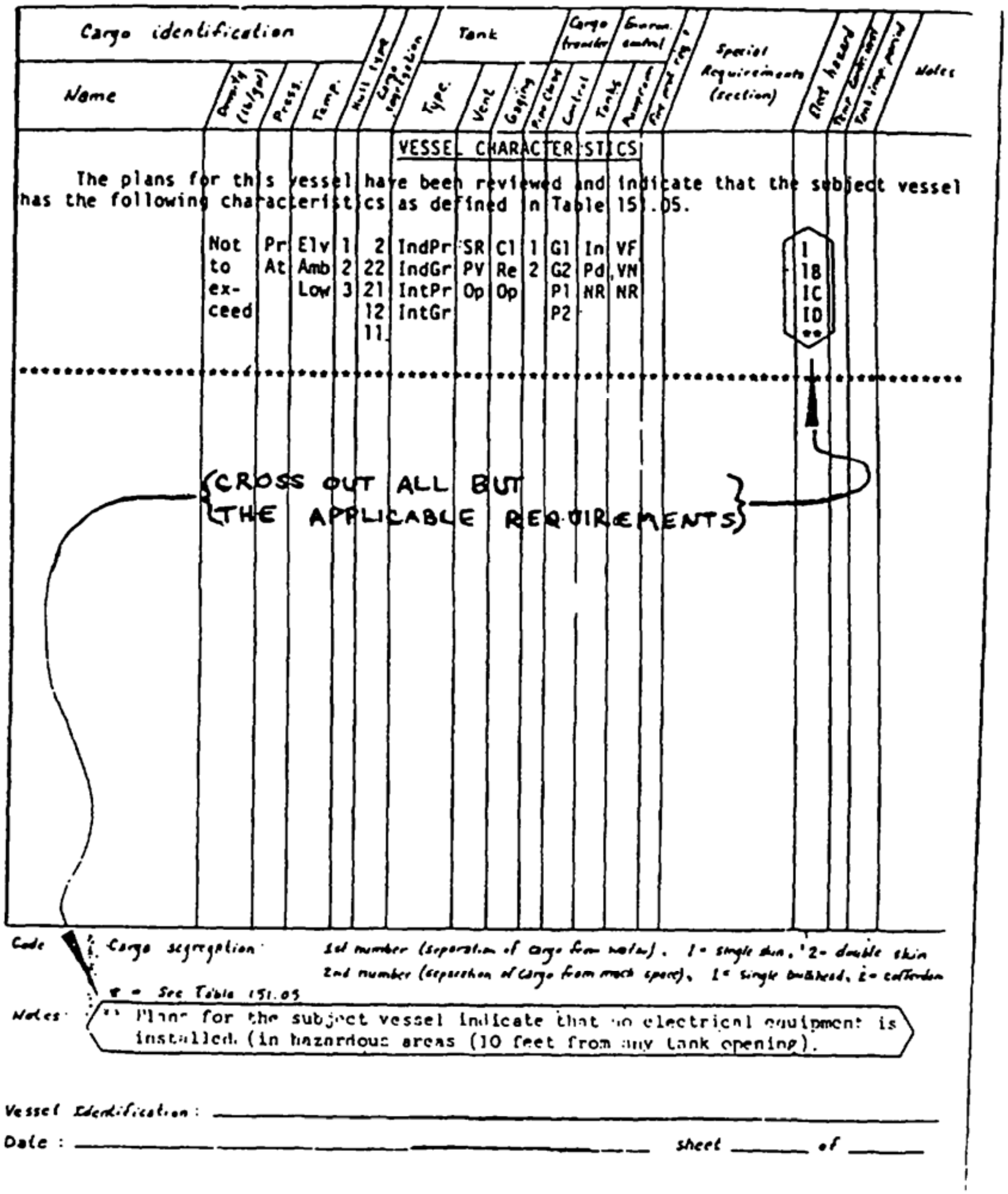
SPECIFIED HAZARDOUS LOCATIONS

LOCATION	CLASS I DIV. 1	CLASS I DIV. 2	CLASS II	CLASS III
CARGO TANKS *	NA	NA	NA	NA
CARGO HANDLING ROOMS*	NA	NA	NA	NA
COFFERDAMS*	NA	NA	NA	NA
BATTERY ROOMS	X	NA	NA	NA
PAINT STORAGE ROOMS	X	NA	NA	NA
PAINT MIXING ROOMS	X	NA	NA	NA
OIL STORAGE ROOMS	X	NA	NA	NA
ANESTHETIC HANDLING AREA	X	NA	NA	NA
TANK VESSEL WEATHERDECK 10 FT. RULE	X	NA	NA	NA
TANK VESSEL WEATHERDECK CARGO BLOCK	X	NA	NA	NA
FLAMMABLE GAS HANDLING ROOM*	NA	NA	NA	NA
FLAMMABLE LIQUID HANDLING ROOM*	NA	NA	NA	NA
ADJACENT TO CLASS I DIV. 1 W/COMMUNICATION	X	NA	NA	NA
TANK VESSEL ENCLOSED SPACES ADJACENT TO CARGO TANK*	NA	NA	NA	NA
GRAIN HANDLING AREA	NA	NA	X	NA
COAL HANDLING AREA	NA	NA	X	NA
COAL PULVERIZING AREA	NA	NA	X	NA
CARPENTER SHOP	NA	NA	NA	X
FIBER HANDLING AREA	NA	NA	NA	X
VENT DUCT		SAME AS SPACE SERVED		
TANK VESSEL CARGO HOSE STOWAGE SPACE*	NA	NA	NA	NA
SPACE CONTAINING CARGO PIPING ONLY, ON TANK VESSELS*	NA	NA	NA	NA
LFG BARRIER SPACE*	NA	NA	NA	NA
ENCLOSED SPACE OPENING TO WEATHER DECK HAZ. AREA	X	NA	NA	NA
TANK VESSELS WITHIN 8' OF CARGO CONTAINMENT SYSTEM	X	NA	NA	NA
TANK VESSELS, WITHIN 10' OF CARGO HANDLING ROOM DOOR OR VENT	X	NA	NA	NA
VESSEL FUEL OIL TANKS, 10' RULE DOES NOT APPLY	X	NA	NA	NA

* These areas are considered more hazardous than Class I, Division 1 and therefore carry specific requirements in 46 CFR 111.105-29, 111.105-31, and 111.105-32.

FIGURE 3-8

SUMMARY OF MINIMUM REQUIREMENTS FOR CARRIAGE OF CERTAIN BULK DANGEROUS CARGOES ON UNMANNED TANK BARGES (Extracted From 46 CFR, Table 151.05)



Cargo identification: Name	Density (lb/gal)	Press.	Temp.	Hull type	Cargo segregation	Tank: Type	Vent	Gaging	Cargo transfer: Pipe class	Control	Environ. control: Tanks	Pumproom	Fire prot. req's	Special Requirements (section)	Elect hazard	Temp. ...	Tank insp. period	Notes
VESSEL CHARACTERISTICS — The plans for this vessel have been reviewed and indicate that the subject vessel has the following characteristics as defined in Table 151.05.	Not to ex- ceed	Pr At	Elv Amb Low	1 2 3	2 22 21 12 11	IndPr IndGr IntPr IntGr	SR PV Op	Cl Re Op	1 2	G1 G2 P1 P2	In Pd NR	VF, VN NR			I IB IC ID **			

{CROSS OUT ALL BUT THE APPLICABLE REQUIREMENTS}

Code: i. Cargo segregation: 1st number (separation of cargo from water). 1 = single skin, 2 = double skin. 2nd number (separation of cargo from machy space). 1 = single bulkhead, 2 = cofferdam

* = See Table 151.05

Notes: ** Plans for the subject vessel indicate that no electrical equipment is installed (in hazardous areas (10 feet from any tank opening).

Vessel Identification: ____________________

Date: ____________________ sheet ______ of ______

FIGURE 3-9

RECOMMENDED PLAN REVIEW CHECK-OFF FOR HAZARDOUS LOCATIONS

1. Has sufficient information been provided?

______(a) Hazardous cargoes;

______(b) An arrangement plan identifying hazardous and non-hazardous areas, cargo system or hazards, electrical equipment type and locations;

______(c) A complete and detailed Bill of Materials;

______(d) Elementary and one—line wiring diagrams, showing all wiring;

______(e) Electrical installation details;

______(f) UL listings, UL service guide letters, Factory Mutual (FM) test reports, Canadian Standards Association (CSA), or other independent test laboratory listings for IS and explosionproof (EP) systems/equipment; and

______(g) Maximum temperature of electrical in hazardous areas.

2. Identify hazardous characteristics:

______(a) Class and group;

______(b) Flashpoint and grade;

______(c) Minimum ignition temperatures; and

______(d) Special requirements, including material compatibility.

3. Confirm boundaries of hazardous locations and suitability of equipment installed.

4. Confirm that the installation meets:

______(a) Subchapter J;

______(b) Intended application by UL, FM, CSA, or other independent test laboratories;

______(c) Specific requirements for the cargo/material; and

______(d) General considerations of this guide.

3.B.2.b(6)

(b) References.

i. NVIC 9-84 (Electrical Installations in Agricultural Dust Locations).

ii. 46 CFR 111.60 (Wiring Materials and Methods).

iii. 46 CFR 111.105 (Hazardous Locations).

iv. 46 CFR 32.45 (Electrical Installation, Tank Vessels).

v. 46 CFR 38.15-15 (Electrical Installation, Liquefied Flammable Gas (LFG) Tank Vessels).

vi. 46 CFR Table 151.05 (Summary of Minimum Requirements, Bulk Dangerous Cargoes).

vii. NFPA 70, National Electrical Code (NEC) Art. 500-503.

viii. National Fire Protection Association (NFPA) 496, "Purged and Pressurized Enclosures for Equipment."

ix. Chemical Data Guide for Bulk Shipment by Water, COMDTINST M16616.6 (series).

x. NFPA 493, "Intrinsically Safe Process Control Equipment.

xi. Instrument Society of America (ISA) Recommended Practice 12.6 – Installation of intrinsically Safe Instrument Systems.

xii. 46 CFR 111.15-5.

xiii. NFPA 77, "Static Electricity."

xiv. Electrical Instruments in Hazardous Locations, Magison.

xv. Chemical Hazard Response Information System (CHRIS), COMDTINST M16465.11 (series).

(c) General Requirements.

i. 46 CFR 111.105 contains the requirements for electrical equipment and wiring in locations where fire or explosion hazards may exist. Electrical installations in these locations require a form of construction and installation that will ensure safe performance under conditions of proper use and maintenance. In these locations, it is necessary to exercise more than ordinary care with regard to the installation and maintenance of equipment and wiring. The primary objective in design is to minimize the amount of electrical equipment installed in hazardous locations.

ii. Through the exercise of ingenuity in the layout of

3.B.2.b(6)(c) ii. (cont'd) electrical installations for hazardous locations, it is frequently possible to locate much of the equipment in less hazardous or in non-hazardous locations and thus reduce the amount of special equipment and installations required. [NOTE: This guidance addresses the requirements for tank vessels, specified hazardous cargoes, and specified hazardous areas. A discussion of this topic, basic requirements for plan review, and an list of references have been provided.]

(d) Classifications.

i. Introduction. Locations are classified depending on the properties of the flammable vapors, liquids, gases, or combustible dusts or fibers that may be present and the likelihood that a flammable or combustible concentration or quantity is present. Hazardous locations are classified by class, group, and division. The explosion characteristics of air mixtures of hazardous gases, vapors, or dusts vary with the specific material involved. Class I locations involve flammable gases or vapors. Class II locations involve combustible dusts, and Class III locations involve easily ignitable fibers or flyings.

ii. Classifying Air Mixtures. For purposes of testing and approval, various air mixtures have been grouped on the basis of three hazardous characteristics. For Class I locations, Groups A, B, C, and D, the classification involves determination of maximum explosion pressure, maximum safe clearance between parts of a clamped joint in an enclosure, and the minimum ignition temperature of the atmospheric mixture. For Class II locations, Groups E and G, the classification involves the tightness of the joints of assembly and shaft openings for preventing entrance of dust in the dust/ignitionproof enclosure, the blanketing effect of layers of dust on the equipment that may cause overheating, electrical conductivity of the dust and the ignition temperature of the dust. It is necessary that equipment be approved not only for the class, but also for the specific group of the gas, vapor, or dust that will be present. Specific vapors may be identified by reference to the NEC, CHRIS, and the Chemical Data Guide.

iii. Classifying Hazardous Locations. Hazardous locations are further classified according to the probability that a hazardous situation exists. Division 1 locations have a higher probability than Division 2 locations. Certain locations, such as cargo handling rooms, are considered to have a still higher probability of a hazardous situation than a Division 1 location. Additional restrictions have been placed on electrical installations in those areas.

3.B.2.b(6)(d)

iv. Classifying Hazardous Liquids. Flammable and combustible liquid cargoes may be further classified according to their vapor pressure and flashpoint (fp). It should be noted that these liquids may be assigned a Class, a Group, and a Grade. In cases when requirements differ, the most conservative requirements should be applied. Each compartment or area should be considered individually in determining its classification. If several different hazardous atmospheres may be present, the most hazardous is to be considered to exist. Hazardous locations and/or permissible equipment for the particular location are described in Title 46, CFR as noted below:

a.	Combustible liquid cargo carriers (fp of 60°C or higher)	111.105-29
b.	Flammable or combustible cargo With a fp below 60°C, liquid and inorganic acid carriers	111.105-31 Sulfur
c.	Bulk liquefied gas and ammonia carriers	111.105-32
d.	Mobile offshore drilling units (MODU's)	111.105-33
e.	Vessels carrying coal	111.105-35
f.	Flammable anesthetics	111.105-37
g.	Gasoline or other highly volatile motor fuel carried in vehicles	111.105-39
h.	Battery rooms	111.105-41
i.	Paint stowage or mixing spaces	111.105-43

(e) Equipment. Specific requirements for electrical equipment in hazardous locations are contained in 46 CFR 111.105. In that subpart, certain equipment is required to be listed by Underwriters Laboratory, Inc. (UL), Factory Mutual research Corporation (FM), Canadian Standards Association (CSA), or another independent laboratory recognized by the Commandant.

(f) General Considerations. The following guidance clarifies the referenced regulations and codes:

i. 46 CFR 38.15-15 And 111.105-32. Requirements for Liquefied Flammable Gas (LFG) installations.

ii. 46 CFR 111.60-5(b). Cable must not be located in any tanks except to supply equipment or instruments specifically designed for and compatible with such location, and whose function require its installation in

3.B.2.b(6)(f)

ii. (cont'd) the tank. The cable must be compatible with the liquid or gas in the tank or be protected by an enclosure.

iii. 46 CFR 111.105-7.

a. Purged and pressurized systems in accordance with NFPA 496 may also be used where explosionproof installations are required.

b. A list of recognized testing laboratories for both explosionproof and IS approvals is posted at http://www.uscg.mil/hq/g-m/mse/lablist.html.

iv. 46 CFR 111.105-11. Intrinsically Safe systems may be used anywhere explosionproof equipment may be used, but the converse is not necessarily true.

v. 46 CFR 111.105-27. Belt drives are acceptable if belt is conductive and grounding is in accordance with NFPA 77.

vi. 46 CFR 111.105-31. See specified Hazardous Locations Table for specific areas.

vii. 46 CFR 111.105-31(b). Note cable locations.

viii. 46 CFR 111.105-31(l).

a. Ten foot rule also applies to tank barges. All equipment within area is to meet Class I, Division 1 requirements. See Figure 3-6.

b. Cargo block rule, ten foot rule, and eight foot rule for exposed cargo containment systems apply. All equipment in these areas shall be Class I, Division 1. See Figure 3-6.

ix. NEC 500-1. Minimize electrical equipment in hazardous areas.

x. NEC 500-2 And 46 CFR Table 151.05. See table for most recent class and group designations.

xi. NEC 501-3(b)(1). Division 2 switching mechanisms must either be in an explosionproof enclosure, or contacts are to be in oil immersion or hermetically sealed chamber with a non-explosionproof enclosure with vent and flame screen. Maximum temperature 80% minimum ignition temperature. General purpose enclosures are allowed for meters, instruments, etc., where the available energy is not sufficient for ignition. Requires specific approval.

xii. NEC 502. Primary factors to be eliminated with dusts are the admission of dust into the enclosure, heat of ignition due to dust buildup and insulating

3.B.2.b(6)(f)

xii. (cont'd) characteristics, and conductive dust-forming current paths.

xiii. Temperature Rating. The temperature rating of all equipment shall not exceed the minimum ignition temperature of the hazardous material. In the past, this temperature was believed to be correlated to the other factors tested in determining groups. In 1971, tests showed there is no predictable correlation, and minimum ignition temperature should be treated individually, in addition to Class and Group. Minimum ignition temperatures can be found in the Chemical Data Guide.

xiv. Division 1 Equipment. Division 1 equipment is satisfactory for Division 2 applications of the same Class and Group.

xv. Electric Oil Immersion Heaters. See 46 CFR 111.85.

xvi. Vent Ducts. Vent ducts shall be the same classification as the space they serve. Vent fans shall be non-sparking. Vent fan motors shall be approved for the locations, or located outside the duct, 10 feet from duct termination, in a non-hazardous area.

(g) Intrinsically Safe (IS) Systems. The following guidance clarifies the applicable regulations:

i. IS systems limit the energy available to the hazardous location by limiting the voltage and current available under normal and fault conditions.

ii. IS systems may be used in any hazardous location but must be approved for the application.

iii. IS systems must be UL, FM, CSA, or other independent test laboratory, recognized by Commandant (G-MSE-3), tested and approved for the intended application, and each component shall be labeled to identify the component, the testing laboratory, and its intended application.

iv. IS systems can only be accepted as whole units by the MSC. Field inspection offices check that the system is applied as intended and that the installation meets the applicable Coast Guard installation requirements. Switching and other devices that do not store energy can be approved when properly applied with approved IS barriers.

v. All cables for use in IS installations must meet the standards of 46 CFR 111.105-11.

vi. Installation requirements:

3.B.2.b(6)(g)vi

a. IS equipment in weather locations must be made watertight.

b. Cable insulation must be appropriate for the hazardous atmosphere (non-reactive).

c. As a general rule, conductors should be no smaller than #18.

d. IS conductors must be isolated from others to prevent compromise due to induction or insulation breakdown.

e. At a termination, IS circuits must be isolated from other IS circuits, other low-energy level circuits, and all power circuits.

f. All IS circuits and cables are to be provided positive mechanical isolation from all power circuits.

g. More than one IS circuit of the same system may be run in single multiconductor cable (see ISA RP 12.6, Section 6.7).

h. IS cables shall carry only IS conductors.

i. Each IS cable must be shielded, 2 inches from non-IS cables, or be partitioned by a grounded metal barrier from other non-IS cables.

(h) <u>Explosionproof (EP) Equipment</u>. The following guidance clarifies the applicable regulations:

i. EP equipment shall be specifically tested and approved for Class I applications by UL, FM, CSA, or other independent test laboratories, and labeled as such.

ii. All components of an "EP" installation must be EP and specified as such by the laboratory. These include enclosure, seal fitting, plugs, drains, seal compound, fiber dam or plug, seal housing, etc.

iii. Factory-sealed EP equipment must have a seal fitting within 18 inches of the enclosure for each cable.

iv. If two EP enclosures are less than 36 inches apart and connected, only one seal is necessary in the conduit between them.

v. EP equipment in weather locations shall be made watertight or waterproof. EP equipment is not usually watertight. Care should be taken in making them watertight that any gasket, etc., does not interfere with the flame-quenching surfaces and that gaskets are external to these surfaces (see Electrical Instruments in Hazardous Locations).

3.B.2.b(6)(h)

vi. EP equipment is not vaportight. Conversely, vaportight equipment is not EP, due to pressure and temperature changes.

vii. See NEC 500 and Figure 3-5 for temperature ratings.

viii. Mineral Insulated (MI) cables require special EP terminal fittings, approved for the application.

ix. Special care should be taken with regard to requirements for EP enclosures as opposed to EP assemblies.

x. Alterations to EP equipment may void its explosionproof capabilities. EP enclosures are approved for certain applications, such as the installation of terminal strips, relays, etc., and may be internally modified to meet these intended applications within the limits specified in the approval. EP assemblies may not be modified in any way. The following items are of concern in modifications:

a. Major alteration to internal volumes and pressure paths, affecting pressure dissipation due to pressure piling;

b. Alteration of flame-quenching paths and surfaces;

c. Alteration of enclosure structural strength and integrity.

These alterations may differ from the configuration as tested by UL, FM, CSA, or other approved laboratories, and should be specifically reviewed.

(i) Purged And Pressurized (P & P) Systems.

i. P & P systems pressurize the atmosphere within an enclosure with a non-hazardous gas, thereby preventing the hazardous atmosphere from coming in contact with electrical equipment within the enclosure.

ii. P & P systems may be used in lieu of EP equipment for all applications except cargo handling rooms, and the system must meet the requirements of NFPA No. 496.

iii. P & P systems need not be approved by a testing laboratory. The MSC may review and approve systems for specific applications.

iv. P & P installations must meet 46 CFR 111.60 requirements.

v. Special care should be taken to ensure that the protective gas is from a non-hazardous source and cannot be contaminated by a hazardous source.

3.B.2.b(6)(i)

vi. Exhaust fans may require interlocking with the supply fans to prevent operation with the supply fans off.

vii. Vent fan operation should be monitored by airflow, not motor operation.

viii. P & P test and maintenance procedures should be provided.

(7) AC Motor Circuits.

(a) Tables.

i. 3-Phase, 208 VAC Branch Circuit Quick Reference Table (Figure 3-10).

ii. 3-Phase, 460 VAC Branch Circuit Quick Reference Table (Figure 3-11).

(b) Code Letters And Branch Circuit Protection.

i. General. The nameplate on a motor rated at 0.5 horsepower or larger must list its code letter (see 46 CFR 111.25-5 and NEC 430-7; this information is very seldom available to the plan reviewer). Code letters are listed alphabetically and represent the locked rotor kilo volt amperes (KVA) per horsepower. The branch circuit protective device chosen must be large enough to allow sufficient time for the motor to start. Higher code letters indicate greater locked rotor currents, requiring larger protective devices. When starting a motor with full voltage, the locked-rotor current does not diminish until the motor is very nearly up to its rated speed. Most motors used have code letters ranging from "F" to "V." For these motors, the maximum rating or setting of the branch circuit protective device, if a fuse, is 300 percent of the motor full-load current; if a circuit breaker, this value must not exceed 250 percent (see 46 CFR 111.70-1 and NEC Table 430-152). The minimum value is not given but must be capable of carrying the starting current of the motor (see subparagraph 3.C.2.g.(3) and NEC 430-52). For vital systems, however, a minimum of 200 percent full-load current is recommended for motors having "F" to "V" code letters, to ensure starting of the motors. The safety of the vessel far outweighs the motor circuit protection in any emergency situation. Use the trip setting values listed in the Quick Reference tables (Figure 3-10 or 3-11), Columns I or J as applicable, to check all motors having code letters "F" through "V."

ii. Motor Running Protection. Running protection for most motor applications is provided by circuit overload elements that take longer to operate but may be set closer to the recommended overload value of 115 percent of the motor's full-load current. The size of the device chosen must be determined from the actual nameplate

3.B.2.b(7)(b) ii. (cont'd) full-load current rating. This information is not available to the plan reviewer and sometimes even the design engineer. The marine inspector should compare the overloads used against the actual nameplate data to ensure that they do not exceed the 115 percent recommended value. Use the values listed in Columns "C" and "D" of Quick-Reference Tables (Figure 3-10 or 3-11), to check the maximum value to be specified for running protection. For additional methods, refer to NEC 430-C.

iii. Motor Controllers Or "Starters".

a. These devices are used to manually or automatically start electric motors from a local or remote location. Motor controllers basically consist of a relay or "contactor," which is used to connect the motor to the AC line by a pushbutton switch, liquid level switch, pressure switch, temperature switch, etc. The two types of controllers used are "low voltage release" (LVR) and "low voltage protection" (LVP). Both types can be identical controllers, but their electrical circuits will vary.

b. LVR controllers are required for vital systems to ensure that the equipment will re-start following a loss of power or reduction in voltage below the "drop-out" value of the operating coil. These starters are usually energized by contacts that must remain closed for the contactor to stay energized.

c. LVP controllers are activated by "momentary" contacts, such as a pushbutton. When the button is depressed, the starter is energized as above, but an additional "auxiliary" normally open contact furnished as part of the controller closes when the "starter" main contacts close. This contact is wired in parallel with the pushbutton and takes its place when the button is released, thus keeping the controller energized or "sealed-in." Should a momentary loss of power and accompanying drop in voltage occur, the starter coil will release all its main and auxiliary contacts and will not re-start following a power outage until the momentary pushbutton contact is again depressed.

d. The above discussion has been limited to the most commonly used method of starting electric motors on marine vessels; that is, by using the same AC source that powers the motor to energize its controller. In certain special applications, AC motor starters could be energized with DC or separate AC sources. Motor controllers are furnished with the thermal overload elements mentioned above. These elements are used to open

3.B.2.b(7)(b)iii

d. (cont'd) (or close) contacts which are used either in the control circuit or to provide an overload alarm to another circuit. Some of these elements are adjustable; most often the non-adjustable type is specified. Most motors are stopped by contacts when an overload occurs to vital systems, such as steering, these devices are used only to signal the overload condition in a separate circuit.

iv. Disconnecting Means. Motor controllers are required with a disconnecting device mounted within the same enclosure. The disconnecting means must disconnect both the motor and controller from all supply conductors (see NEC 430 part IX).

v. Reference Tables.

FIGURE 3-10

3-PHASE, 208 VAC MOTOR CIRCUIT QUICK-REFERENCE TABLE
FOR SINGLE BANKED CABLES

A	B	C	D	E	F	G	H	I	J
HP	FLA	Running Prot. 115% FLA. Adj.	Running Prot. 115% FLA. Non-Adj.	Starter Size	Discon-nect Size	Max. Full Code C.B. 200%	Prot. Device Volt Start B-E Fuse 250%	Prot. Device Volt Start Code C.B. 250%	Prot. Device F-V Fuse 300%
.25	1.23	1.41	2	00	30	15	15	15	15
.33	1.48	1.7	2	00	30	15	15	15	15
.5	2.0	2.3	3	00	30	15	15	15	15
.75	2.8	3.22	4	00	30	15	15	15	15
1	3.6	4.14	4	00	30	15	15	15	15
1.5	5.7	6.56	8	00	30	15	15	15	15
2	7.8	8.97	10	0	30	20	20	20	20
3	10	11.5	12	0	30	20	30	30	30
5	17	19.6	20	1	60	35	40	50	60
7.5	24	27.6	30	1	60/100	50	50	70	80
10	31	35.7	40	2	100	70	70	90	100
15	46	52.9	60	3	100/200	100	100	125	150
20	59	67.9	70	3	200	125	125	150	200
25	75	86.3	100	3	200/400	175	175	200	250
30	88	101	110	3	200/400	200	200	125	300
40	114	131	150	4	400	250	250	300	350
50	143	164	200	4	400/600	300	300	400	450
60	170	196	225	5	400/600	350	350	500	500
75	212	243	250	5	600	500	500	600	—
100	273	314	350	5	600	600	600	—	—
125	343	394	450	6	—	—	—	—	—
150	396	455	500	6	—	—	—	—	—
200	528	607	800	6	—	—	—	—	—

FIGURE 3-10 (cont'd)

3-PHASE, 208 VAC MOTOR BRANCH CIRCUIT QUICK-REFERENCE TABLE

HP	K	L	M	N	O	P
	125% FLA	THREE CONDUCTOR BRANCH CABLE				
		AWG (IEEE 45, 50°C)			TSGA – ( )	
		T	E,X	AVS	40°C	50°C
.25	1.54	14	14	14	4	4
.33	1.85	14	14	14	4	4
.5	2.51	14	14	14	4	4
.75	3.5	14	14	14	4	4
1	4.5	14	14	14	4	4
1.5	7.13	14	14	14	4	4
2	9.75	14	14	14	4	4
3	12.5	14	14	14	4	4
5	21.3	12	14	14	9	9
7.5	30.0	10	10	12	9	9
10	38.8	7	8	10	9	14
15	57.5	5	6	7	23	23
20	73.8	3	4	5	30	30
25	93.8	1	2	3	40	50
30	110.0	1/0	1	2	50	60
40	142.5	3/0	2/0	1/0	75	100
50	178.8	4/0	3/0	2/0	125	125
60	212.5	300	250	4/0	150	150
75	265.0	400	350	250	200	250
100	341.3	600	500	400	300	400
125	428.8	—	—	—	400	—
150	495.0	—	—	—	—	—
200	660.0	—	—	—	—	—

FIGURE 3-11

3-PHASE, 460 VAC MOTOR BRANCH CIRCUIT QUICK-REFERENCE TABLE

A	B	C	D	E	F	G	H	I	J
HP	FLA	Running Prot. 115% FLA		Starter Size	Discon-nect Size	Max. Full Prot. Device Volt Start			
		Adj.	Non-Adj.			Code C.B. 200%	B-E Fuse 200%	Code C.B. 250%	F-V Fuse 300%
.5	1	1.15	2	00	30	15	15	15	15
.75	1.4	1.61	2	00	30	15	15	15	15
1	1.8	2.07	3	00	30	15	15	15	15
1.5	2.6	2.99	3	00	30	15	15	15	15
2	3.4	3.91	4	00	30	15	15	15	15
3	4.8	5.52	6	0	30	15	15	15	15
5	7.6	8.74	10	0	30	20	20	20	25
7.5	11	12.65	15	1	30/60	25	30	30	35
10	14	16.1	20	1	30/60	30	35	35	45
15	21	24.15	25	2	60/100	45	60	60	70
20	27	31.05	35	2	60/100	60	70	70	90
25	34	39.1	40	2	100/200	70	90	90	110
30	40	46	50	3	100/200	90	100	100	125
40	52	59	60	3	200	125	150	150	175
50	65	74.75	80	3	200	150	175	175	200
60	77	88.55	90	4	200/400	175	200	200	250
75	96	110.4	125	4	400	200	250	250	300
100	124	142.6	150	4	400	250	350	350	400
125	156	179.4	200	5	400/600	350	400	400	500
150	180	207	225	5	600	400	450	450	600
200	240	276	300	5	600	500	600	600	—

FIGURE 3-11 (cont'd)

HP	K	L	M	N	O	P
	125% FLA	THREE CONDUCTOR BRANCH CABLE				
		AWG (IEEE 45, 50°C)			TSGA –( )	
		T	E,X	AVS	40°C	50°C
.5	1.25	14	14	14	4	4
.75	1.75	14	14	14	4	4
1	2.25	14	14	14	4	4
1.5	3.25	14	14	14	4	4
2	4.25	14	14	14	4	4
3	6	14	14	14	4	4
5	9.5	14	14	14	4	4
7.5	13.75	14	14	14	4	4
10	17.5	14	14	14	4	9
15	26.25	10	10	12	9	9
20	33.75	8	10	10	9	9
25	42.5	7	8	8	14	14
30	50	6	7	7	14	23
40	65	4	5	6	23	23
50	81.25	2	3	4	30	40
60	96.25	1	2	3	40	50
75	120	2/0	1/0	1	60	75
100	155	3/0	2/0	1/0	100	100
125	195	250	4/0	3/0	125	150
150	225	300	250	4/0	150	200
200	300	500	400	300	250	300

(c) Examples of 3-Phase AC Motor Circuits. Use Quick-Reference Columns, Figure 3-10:

i. Example No. 1. Single motor, 25 horsepower, 460V, code letter J, full voltage start, non-vital, non-adjustable overloads, branch circuit protected by circuit breaker, Type T, IEEE 45 Cable, in 50°C ambient temperature space.

From Quick-Reference Columns, Figure 3-11:

D - Standard overload size nearest 115 percent full load; current is 40 amperes.

E - Starter size is 2.

F - If a disconnect is used near the motor, a 100 ampere size is sufficient, provided it is not fused above 100 amperes (if fusible). If part of a combination starter, the complete unit must be rated to handle the 25-horsepower motor.

3.B.2.b(7)(c) i. (cont'd) I - The maximum standard size for the branch circuit protective device is a 90 ampere breaker.

K - The cable used to power the motor must be rated for at least 42.5 amperes. For Type T cable in a 50°C ambient location Type T-7 is required.

ii. Example No. 2. A 460 volt Motor Control Center (MCC) supplying one 30 HP, one 15 HP, and two 5 HP motors in 50°C ambient space. The 5 HP motors are steering systems pumps. All are full-voltage starting; the 30 HP motor starter has adjustable overloads. The unit has branch circuit protection with circuit breakers. Navy-type cable TSGA is used. First get data for each motor load; assume code letters F-V.

From Quick-Reference Columns, Figure 3-11:

Col. A	Col. B	Col. C	Col. E	Col. F	Col. I	Col. K	Col. P
Horse-Power	Full Load Amps	Adj. Over Load Size	Start-er Size	Std. Disc. Size, If Used	Max. Branch Circ. Bkr. (250%)	125% F.L.A.	50°C TSGA-( )
30	40	46	3	100	100	50	23
15	21	24.2	2	60	60	26.3	9
5	7.6	8.7	0	30	N/A	9.5	4

Bus or cable in MCC must be sized for 125 percent of the largest plus 100 percent of the remaining motor full load currents, 50 + 21 + 7.6 = 86.2 amperes. If the MCC has spare sections, allowance shall be made for future growth. Breaker protecting entire MCC must not be larger than 100+21+7.6+7.6 or 136.2 amperes.

A 125 amp circuit breaker would be adequate.

The 5 HP steering pump motors should be protected with circuit breakers having adjustable, instantaneous (magnetic) type tripping only. These breakers must be set to open the motor circuit at 175 to 200 percent of the locked rotor current. From subparagraph 3.C.2.h below, these settings should be 79 to 90 amperes.

(8) Tables, Diagrams, And Formulas.

(a) NEMA Enclosures. ICS 1-110, NEMA STDS.

TYPE	DESCRIPTION	PROTECTION
	General Purpose, Indoor	Personnel and Falling Dirt
2	Drip-proof, Indoor Falling Liquids	Personnel, Dirt, Non-Corrosive
3	Dust- and Raintight, Sleet- and Ice-Resistant, Outdoor	Personnel, Outdoor Windblown Dirt and Water
3R	Rainproof, Sleet and Ice	Personnel, Self-Explanatory

3.B.2.b(8)(a) (cont'd)

3S	Dusttight, Raintight, Sleet- and Ice-Proof, Outdoor	Personnel, Self-Explanatory
4	Watertight and Dusttight,	Personnel, Falling and Splashing
	Indoor and Outdoor	Dirt and Water, Sleet-
4X	Watertight, Dusttight, Corro- sion-Resistant, Indoor and Outdoor	Resistant, Personnel, Self-Explanatory
70	Submersible, Watertight, Dusttight, Sleet- and Ice- Resistant, Indoor and Outdoor	Personnel, Self-Explanatory
7	Class I, Groups A – D Air Break	Hazardous Locations, Indoor
8	Class I, Groups A – D Oil-Immersed	Hazardous Locations, Indoor
9	Class II, Groups E – G Air Break	Hazardous Locations, Indoor
10	Bureau of Mines	
11	Corrosion-Resistant and Drip- proof, Oil-Immersed, Indoor	Corrosive Liquids
12	Industrial Use, Dusttight and Driptight, Indoor Liquids	Dirt and Non-Corrosive Dripping
13	Oiltight and Dusttight, Indoors	Self-Explanatory

(b) <u>Common Abbreviations.</u>

a	amperes
AC	alternating current
Al	aluminum
alt	alteration
amb	ambient
AVC	asbestos-varnished, cambric-insulated cable
AWG	American Wire Gage
bhd	bulkhead-mounted
B/M	bill of material
C	degrees Centigrade
chg	change
Class I, Class II, etc.	(see NEC 500)
cond	conductor
corr	corrosive
CSA	Canadian Standards Association
Cu	copper
Cu in	cubic inches
cy	cycles
DC	direct current
D/G	Diesel generator
dp	double pole
dp	dripproof
dpdt	double pole, double throw
dpst	double pole, single throw
dwg	drawing
EP	explosionproof
F	degrees Fahrenheit
fig	figure

3.B.2.b(8)(b) (cont'd)

FM	Factory Mutual
gnd	ground
Group A, Group B, etc.	(see NEC 500)
haz	hazardous
HP	horsepower
IC	interrupting current
incand	incandescent
incl	inclusive
inst	instantaneous
IS	intrinsically safe
KVA	kilo volt amperes
KW	kilowatt
L.C.L.	light center length
LVP	low voltage protection
LVR	low voltage release
max.	maximum
M.I.	mineral insulated, metal sheathed
min	minimum
mod	model
mtg	mounting
NEC	National Electrical Code
nwt	non-watertight
p	pole
ped	pedestal
pend	pendant
PF	power factor
ph	phase
port	portable
psi	pounds per square inch
pt	point
PYRO	pyrometer
R	rubber-insulated cable
refl	reflector
rev	revision
SCR	semiconductor controlled rectifier
sp	single pole
spdt	single pole, double throw
S.P. Phone	sound-powered phone
SS	ship service
SWBD	switchboard
sym	symbol
T	thermoplastic insulated cable
term	terminal
Temp	temperature
T/G	turbine generator
UL	Underwriters Laboratories, Inc.
uv	under voltage
v	volts
VC	varnished cambric-insulated
w	watts or wire
wt	watertight
w/	with
#	catalog number(s)
&	and
@	at

3.B.2.b(8) (c) NEMA AC General Purpose, Class A Full Voltage Controllers, Single-Speed Squirrel Cage Motors.

3-PHASE NON-JOGGING DUTY

SIZE	CONTINUOUS DUTY AMPS	HORSEPOWER 200 VAC	230 VAC	460 VAC	LIMIT AMPS
00	9	1.5	1.5	2	11
0	18	3	3	5	21
1	27	7.5	7.5	10	32
2	45	10	15	25	52
3	90	25	30	50	104
4	135	40	50	100	156
5	270	75	100	200	311
6	540	150	200	400	621
7	810		300	600	932

3-PHASE JOGGING DUTY

SIZE	CONTINUOUS DUTY AMPS	HORSEPOWER 200 VAC	230 VAC	460 VAC	LIMIT AMPS
0	18	1.5	1.5	2	21
1	27	3	3	5	32
2	45	7.5	10	15	52
3	90	15	20	30	104
4	135	25	30	60	156
5	270	60	75	150	311
6	540	125	150	300	621

NOTE: From NEMA ICS 2-321 B

(d) Motor Conversion Formulas.

TO FIND	DC	AC-Single Phase	AC 3 Phase
AMPS when HP is known	$\frac{HP \times 746}{Volts \times Eff}$	$\frac{HP \times 746}{Volts \times Eff \times PF}$	$\frac{HP \times 746}{Volts \times 1.73 \times Eff \times PF}$
AMPS when KW is known	$\frac{KW \times 1000}{Volts}$	$\frac{KW \times 1000}{Volts \times PF}$	$\frac{KW \times 1000}{Volts \times 1.73 \times PF}$
AMPS when KVA is known		$\frac{KVA \times 1000}{Volts}$	$\frac{KVA \times 1000}{Volts \times 1.73}$
Kilowatts KW	$\frac{AMPS \times Volts}{1000}$	$\frac{AMPS \times Volts \times PF}{1000}$	$\frac{AMPS \times Volts \times 1.73 \times PF}{1000}$
KVA		AMPS x Volts	AMPS x Volts x 1.73
Power Factor PF		KW/KVA	KW/KVA
HP Output	$\frac{AMPS \times Volts \times Eff}{746}$	$\frac{AMPS \times Volts \times Eff \times PF}{746}$	

$$\frac{AMPS \times Volts \times 1.73 \times Eff \times PF}{746}$$

3.B.2.b(8)(d) (cont'd)

NOTES: (1) Power factor and Efficiency should be expresses in decimals.

(2) If Power Factor is not given, assume 0.8

(3) If Efficiency is not given, assume 0.8

(e) Single Phase Motor: Approximate Load Current.

HP	115V	HP	115V
.33	7.2	2	24.0
.5	9.8	3	34.0
.75	13.8	5	56.0
1.0	16.0	7.5	80.0
1.5	20.0	10	100.0

NOTES: (1) Values are for motors of normal speed and torque.

(2) For additional values, see NEC table 430-148.

(3) For other KW ratings, voltages, and power factors:

$$\text{AMPS} = \frac{\text{KW} \times 1000}{1.732 \times \text{Volts} \times \text{PF}}$$

(f) Motor Locked Rotor Current.

Max. HP	115VAC 1 Phase			208VAC 3 Phase			230VAC 3 Phase			460VAC 3 Phase		
	100%	175%	200%	100%	175%	200%	100%	175%	200%	100%	175%	200%
2	144	252	288	43	75	86	39	68	78	20	35	40
3	204	357	408	59	103	118	54	95	108	27	47	54
5	336	588	672	99	173	198	90	158	180	45	79	90
7.5	480	840	960	145	254	290	132	231	264	66	116	132
10	600	1050	1200	178	312	356	162	284	324	84	147	168
15				264	462	528	240	420	480	120	210	240
20				343	599	686	312	546	624	156	273	312
25				422	739	844	384	672	768	192	336	384
30				515	901	1030	468	819	936	234	410	468
40				686	1201	1372	624	1092	1248	312	546	624
50				825	1444	1650	750	1313	1500	378	662	756
75				1221	2137	2442	110	1943	2220	558	977	1116
100				1624	2874	3248	1476	2583	2952	738	1292	1476

NOTES: (1) These values are to be used only if motor code letter is not provided.

(2) Values above calculated from NEC Tables 430-150, 430-151.

(3) If motor nameplate code letter is provided, the following applies:

3.B.2.b(8)(f) (cont'd)

(a) See NEC Table 430-7(b) for code letter KVA/HP; and

(b) Locked rotor current, IL:

$$\text{3-Phase motors IL} = \frac{\text{HP x (KVA/HP) x 1000}}{\text{1.73 x Volts}}$$

$$\text{3-Phase motors IL} = \frac{\text{577 x HP x (KVA/HP)}}{\text{Volts}}$$

$$\text{1-Phase motors IL} = \frac{\text{HP x (KVA/HP) x 1000}}{\text{Volts}}$$

(g) Continuous-Duty, 3-Phase Motor Approximate F.L.A.

HP	Squirrel Cage			Wound Rotor		
	208V	220V	440V	208V	220V	440V
.5	2.1	1.9	.95			1.0
1	3.7	3.4	1.7	5.9	5.4	2.7
1.5	5.5	5.0	2.5	7.5	6.8	3.4
2.0	6.9	6.3	3.1	8.8	8.0	4.0
2.5	8.4	7.6	3.8	9.7	8.8	4.4
3.0	9.9	9.0	4.5	11.5	10.5	5.3
5.0	16.0	14.5	7.2	17.6	16.0	8.0
6.0	18.9	17.2	8.6	19.8	18.0	9.0
7.5	23	21	10.5	25.3	23	11.5
9.0	27.3	24.8	12.4	28.6	26	13
10	28.6	26	13.5	31.9	29	14.5
20	57.2	52	26	59	54	27
25	71.5	65	32	75	68	34
30	86	78	39	88	80	40
35	101	92	46	103	94	47
40	112	102	51	114	104	52
45	128	116	58	128	116	58
50	139	126	63	141	128	64
60	167	152	76	169	154	77
75	207	188	94	207	188	94
100	275	250	125	275	250	125
125	341	310	155	341	310	155
150	407	370	185	407	370	185
200	539	490	245	539	490	245

NOTES:

(1) To be used in lieu of nameplate data (see NEC 430-6).

(2) Not to be used to size motor running overloads; use nameplate data.

(3) For multi-speed, low speed, special motors, use nameplate data.

(4) For additional information, see NEC Table 430-150.

(5) Range: 220V 220-240VAC
440V 440-480VAC

3.B.2.b(8) (h) Miscellaneous Tables.

CURRENT RATING, RECTANGULAR BUS BARS ON EDGE, 50°C AMB., 50°C RISE, IEEE 45-1983, A27 SINGLE BARS IN PARALLEL, COPPER.

SIZE (inches)	DC	AC, 60HZ
3/4 x 1/8	250	250
1 x 1/8	330	330
1-1/2x 1/8	500	500
1-1/2x 3/16	580	570
2 x 3/16	760	745
1 x 1/4	490	480
1-1/2x 1/4	685	675
2 x 1/4	920	900
3 x 1/4	1380	1280
4 x 1/4	1730	1650
5 x 1/4	2125	2000
6 x 1/4	2475	2300
8 x 1/4	3175	2875

MINIMUM SWITCHBOARD SPACINGS (inches)

VOLTAGE	LIVE PARTS, OPP. POLARITY, OVER SURFACE	LIVE PARTS, OPP. POLARITY, THRU AIR	BETWEEN LIVE PARTS & GROUNDED DEAD METAL
125V or Less	3/4	1/2	1/2
126V - 250V	1-1/4	3/4	1/2
251V - 600V	2	1	1

From NEC Table 384-26

NEUTRAL GROUNDING CONDUCTORS, AC SYSTEMS

A.W.G. OF LARGEST GENERATOR CONDUCTOR OR EQUIVALENT FOR PARALLEL GENS.			A.W.G. OF GROUND CONDUCTOR
up to #2			#8
#2	--	#0	#6
#0	--	3/0	#4
3/0	--	350 MCM	#2
350 MCM	--	600 MCM	#0
600 MCM	--	1100 MCM	2/0
greater than 1100 MCM			3/0

See 46 CFR 11.05-31(b).

3.B.2.b(8) (i) Generator Continuous Full Load Ampere Ratings.

3-PHASE 0.8 Power Factor

			115%		115%		115%		115%		115%		115%
KW	KVA	208V	FLA	230V	FLA	240V	FLA	460V	FLA	480V	FLA	600V	FLA
5.0	6.3	17.5	20	15.8	18	15.2	17	7.9	9	7.6	9	6.1	7
7.5	9.4	26.1	30	23.6	27	22.6	26	11.8	14	11.3	13	9.0	10
10.0	12.5	34.7	40	31.4	36	30.1	35	15.7	18	15.0	17	12.0	14
15.0	18.7	52.0	60	47.0	54	45.0	52	23.5	27	22.5	26	18.0	21
20.0	25.0	69.4	80	62.8	72	60.1	69	31.4	36	30.1	35	24.1	28
25.0	31.3	87.0	100	78.6	90	75.3	87	39.1	45	37.6	43	30.1	35
30.0	37.5	104.1	120	94.1	108	90.2	104	47.1	54	45.1	52	36.1	42
40.0	50.0	138.8	160	125.5	144	120.3	138	62.7	72	60.1	69	48.1	55
50.0	62.5	173.5	200	156.9	180	150.3	173	78.4	90	75.2	86	61.1	70
60.0	75.0	208.2	239	188.3	217	180.4	207	94.1	108	90.2	104	72.2	83
75.0	93.8	260.4	300	235.4	271	225.6	259	117.7	135	112.8	130	90.3	104
100.0	125.0	347.0	399	313.8	361	300.7	346	156.9	180	150.4	173	120.3	138
125.0	156.0	433.0	498	391.6	450	375.3	432	195.8	225	187.6	216	150.1	173
150.0	187.0	519.1	597	469.4	540	449.8	517	234.7	270	224.9	259	179.9	207
175.0	219.0	607.9	699	549.6	632	526.7	606	274.8	316	263.3	303	210.7	242
200.0	250.0	694.0	798	627.6	722	601.4	692	313.8	361	300.7	346	240.6	277
250.0	312.0	866.1	996	783.2	900	750.5	863	391.6	450	375.3	432	300.2	345
300.0	375.0	1040.1	1196	941.3	1082	902.1	1037	470.7	541	451.1	519	361.0	415

NOTES: (1) Generator cables shall be capable of carrying at least 115 percent generator continuous F.L.A. (see 46 CFR 111.60-7).

(2) Generator circuit breaker long time overcurrent trip shall not exceed 115 percent generator continuous F.L.A. (see 46 CFR 111.12-11).

3.B.2.b(8) (j) Transformer Full Load Currents.

FULL LOAD CURRENTS
3-PHASE TRANSFORMERS
Voltage (Line to Line)

KVA Rating	208	240	480	800	2400	4180
3	8.3	7.2	3.6	2.9	.72	.415
6	16.6	14.4	7.2	5.8	1.44	.83
9	25	21.6	10.8	8.7	2.16	1.25
15	41.6	36.0	18.0	14.4	3.6	2.1
30	83	72	36	29	7.2	4.15
45	125	108	54	43	10.8	5.25
75	208	180	90	72	18	10.4
100	278	241	120	96	24	13.9
150	416	360	180	144	36	20.8
225	625	542	271	217	54	31.2
300	830	720	360	290	72	41.5
500	1390	1200	600	480	120	69.4
750	2080	1800	900	720	180	104
1000	2775	2400	1200	960	240	139
1500	4150	3600	1800	1440	360	208
2000	5550	4800	2400	1930	480	277
2500	6950	6000	3000	2400	600	346
5000	13900	12000	8000	4800	1200	694
7500	20800	18000	9000	7200	1800	1040
10000	27750	24000	12000	9600	2400	1366

For other KVA Ratings or Voltages:

$$\text{Amperes} = \frac{\text{KVA} \times 1000}{\text{Volts} \times 1.732}$$

3.B.2.b(8)(j) (cont'd)

FULL LOAD CURRENTS
SINGLE PHASE TRANSFORMERS
Voltage

KVA Rating	120	208	240	480	600	2400
1	8.34	4.8	4.16	2.08	1.67	.42
3	25	14.4	12.5	6.25	5.0	1.25
5	41.7	24.0	20.8	10.4	8.35	2.08
7.5	62.5	36.1	31.2	15.6	12.5	3.12
10	83.4	48	41.6	20.8	16.7	4.16
15	125	72	62.5	31.2	25.0	6.25
25	208	120	104	52	41.7	10.4
37.5	312	180	156	78	62.5	15.6
50	417	240	208	104	83.5	20.8
75	625	361	312	156	125	31.2
100	834	480	416	208	167	41.6
125	1042	800	520	260	208	52.0
167.5	1396	805	698	349	279	70.0
200	1666	960	833	416	333	83.3
250	2080	1200	1040	520	417	104
333	2776	1600	1388	694	555	139
500	4170	2400	2080	1040	836	208

For other KVA Ratings or Voltages:

$$\text{Amperes} = \frac{\text{KVA x 1000}}{\text{Volts}}$$

C. Equipment.

1. Acceptable Equipment.

a. Introduction.

(1) Type Approvals. The Coast Guard only grants type approvals for the electrical, lifesaving and engineering equipment listed in 46 CFR, Subchapter Q. All other equipment is to meet the requirements of the applicable subchapter. The determination as to acceptability will be made through plan review and inspection on an individual basis by the MSC or the OCMI, respectively. Equipment that is required to meet a certain UL standard need not be listed by UL, but must be constructed and inspected to that standard. Equipment that is listed by UL should generally be accepted as meeting this requirement without further review.

(2) FAQ. Frequently Asked Questions:

(a) What equipment is supposed to be Coast Guard approved? All equipment installed on vessels subject to Coast Guard inspection and certification is subject to some degree of inspection and approval. Certain items are subject to inspection and approval even when carried aboard vessels not required to be inspected and certificated, such as fishing vessels and yachts. The extent of inspection and the type of approval varies with the requirements of laws and

3.C.1.a(2) (a) (cont'd) regulations, as well as the hazards involved. In judging the quality and suitability of equipment used on vessels, the primary considerations are safety of the vessel, safety of personnel, and performance of a safety function. Various items of lifesaving, firefighting, pollution prevention equipment, and miscellaneous equipment used aboard inspected and uninspected vessels are required by statutes and regulations to be of types that are "approved" by the Coast Guard. To be an "approved" type, equipment must be manufactured in accordance with standards published in Title 46 Code of Federal Regulations Subchapter Q, or when specifically permitted by regulation, must comply with the standards of a classification society that is recognized by the Commandant. To this end, the manufacturer must submit plans and specifications to the Coast Guard. The manufacturer is also responsible for the necessary tests or inspection of the device as required by regulations. Upon its approval, the product must be labeled so that it can be identified as approved equipment. The equipment is assigned an individual approval or certification number. The Coast Guard Internet site http://www.uscg.mil/hq/g-m/mse/mse-home.htm lists those equipment that require USCG approval.

(b) Why can't I get Coast Guard Approval for my equipment? Coast Guard approval is not a product endorsement. The Coast Guard does not try to be a "consumer's bureau" for buyers, or a "marketing promotion bureau" for manufacturers. Many inventors and enterprising manufacturers have often tried to get the Coast Guard to approve such things as man overboard alarms, shark repellents, distress kites and balloons. The inability to obtain Coast Guard approval for such devices does not indicate that they are bad ideas, but only that there are no Coast Guard regulations requiring them on any vessel. The purpose of Coast Guard approval is not to provide marketing assistance to manufacturers, but to provide information to vessel owners concerning equipment that has been found to meet the regulatory requirements.

(c) What does the Coast Guard Certificate of Approval mean? The certificate of approval is issued to the manufacturer of the equipment and is normally valid for 5 years. The manufacturer will often supply the consumer a copy of the certificate to keep on board the vessel. The approval of the item covered by the certificate is valid only so long as the item is manufactured in conformance with the details of the approved drawings, specifications, or other reference data. No modification in the approved design, construction, or materials is to be adopted until the Coast Guard has presented the modification for consideration and confirmation received that the proposed alteration is acceptable.

Equipment required meeting standards listed in 46 CFR 110.10-1(b): Equipment required meeting standards found in 46 CFR 110.10-1(b) are usually certified by the manufacturer to be in accordance with these standards. The manufacturer's marking on the item usually indicates compliance with the standard.

3.C.1.a(2) (c) (cont'd) The regulations sometimes require equipment to meet UL Standards. For these items listing by UL is not required. The UL Listing Mark on the equipment is the manufacturer's representation that the completed product has been tested by UL to a nationally recognized safety standard. Those items that require certification from a nationally recognized testing laboratory or require listing marks will have the requirement specifically called out in the regulations.

b. Acceptance Standards.

(1) General. The standards that are referenced for electrical systems and equipment are listed in 46 CFR 110.10-1. Except where it is specified that equipment must be labeled in accordance with an industry standard, only general compliance with the standard is required. Equipment required to meet a UL standard need not have a UL label, though some equipment requires evidence of listing, such as fuses (46 CFR 111.53-1). Other equipment is required to be tested to a specified standard by a Coast Guard Accepted Independent Laboratory, for example hazardous area equipment (46 CFR 111.105, list of accepted labs available at: http://www.uscg.mil/hq/g-m/mse/mse-home.htm). Certain equipment, such as lifesaving and firefighting systems, is required to be formally approved in accordance with Subchapter Q. An agreement between the United States of America (US) and the European Community (EC) on mutual recognition of certificates of conformity of marine equipment became effective on 01 July, 2004. This agreement allows reciprocal approvals to be given by both the US and the EC for certain marine products where it has been found that the approval process is identical or equivalent. Complete information regarding this arrangement can be found in the "Guide to Marine Equipment Approvals Covered by US-EC MRA", COMDTPUB P16700.4, NVIC 8-04.

(2) Standards Updates. The regulations reference many industry standards. For the most part, these standards are dynamic and ever-changing. The "official" referenced edition of an industry standard is listed in the "Finding Aids section of the CFR. Often, that edition may not be the latest edition of the standard. This could create availability problems; where the requirements of a standard have changed, and where manufacturers have modified their equipment to meet the later version, equipment may not be available that meets the referenced edition. However, standard changes often respond to an identified problem or hazard, and usually result in safer equipment. In most instances, equipment constructed and tested in accordance with a more recent edition of a referenced document can be accepted as providing a level of safety equivalent to that provided by equipment constructed and tested to the edition identified in the CFR.

(3) Equivalency. One of the purposes of the Marine Inspection Program is to provide passengers and crew on U.S. flag vessels with an environment that has a level of safety comparable to that ashore. In most domestic "land" installations, electrical equipment is of U.S. manufacture and is listed by an independent

3.C.1.b (3) (cont’d) electrical equipment certification agency acceptable to the governing jurisdiction. In the majority of installations in this country, the equipment is listed by Underwriters Laboratories Inc. (UL). The existing Coast Guard Electrical Engineering Regulations evolved from this situation. With the movement of U.S. flag construction abroad, there has been an influx of electrical equipment that is constructed to meet other standards and that is listed by independent third party certifying agencies similar to UL. Some equipment is built to manufacturer's standards and is not third party certified. Both of these types of equipment need to be evaluated for equivalence to the standards referenced in the Electrical Engineering Regulations before acceptance for installation.

The Electrical Engineering Regulations require many electrical items to meet a specific UL Standard. For such items, listing by UL is not required. While evidence of such listing may be the most expeditious method to determine compliance, it is not the only method. 46 CFR 110.25-1 calls for the submission of plans and information to evaluate equipment required to meet a referenced standard. Equipment may be accepted by having evidence of listing, by manufacturer's certification, or by determining the standard it does meet is equivalent to the referenced standard.

(4) Manufacturer Certification. Equipment required to meet an IEEE or NEMA standard or a military specification (e.g. cable or switchgear) is usually certified by the manufacturer to be in accordance with the standard. Equipment manufactured in the U.S. is usually designed to these standards, and it is not uncommon for foreign equipment to be designed to these standards. The manufacturer's marking on the item usually indicates compliance with the standard. This is adequate to demonstrate compliance with the regulations.

(5) Standards Comparisons. More commonly, however, foreign equipment is designed to foreign national and/or International Electrotechnical Commission (IEC) standards, and compliance with, or equivalence to, the referenced document must be determined. The usual starting point for an equivalency determination has been the "line-by-line comparison" demonstrating that the construction and testing of the particular equipment meets, or is "equivalent" to, the referenced document.

(a) Standards Comparisons Guidelines. Evaluation efforts must involve the exercise of "good engineering judgment" to reduce the burdens of line-by-line comparisons imposed on a case-by-case basis. Although "good engineering judgment" is typically "something someone didn't have when something happened that shouldn't have," there are several basic guidelines that recognize limited review resources and that are appropriate in assessing electrical equipment equivalency:

i. The level of evaluation should be commensurate with the level of risk imposed by the item. For example, an outlet box is a relatively simple passive item, 3.C.1.b(5)(a)

i. (Cont’d) providing protection and access to a few simple components, while a circuit breaker is a complex active device that is designed to operate at varying times under both small overloads and large damaging faults, providing system-wide protection. The evaluation of a circuit breaker should be far more involved than the review of an outlet box. This does not mean that evaluation of an outlet box is not important; however, the evaluator should not need to spend an inordinate amount of time to obtain a reasonable level of confidence that the equipment will perform in a safe manner. The evaluator should ask some basic questions: "What will happen if this equipment fails? Will someone be shocked? Will it start a fire? Will a failure be readily apparent during normal operations or will it be hidden and gradually worsen? Does the system design provide additional safety measures that mitigate the effect of the failure? How likely is this failure?"

ii. The evaluator should have a reasonable level of confidence in the equipment. Obtaining this level of confidence with equivalencies often involves subjective judgments concerning the manufacturer as well as specific, technical determinations regarding the hardware itself. A well-known manufacturer that has been in business for an extended period, is a recognized leader in his field, has contributed to the development of industry standards, and has a solid reputation may not need close scrutiny. On the other hand, a "newcomer" to the equipment field or U.S. market place, or an organization that is outside its primary business, such as a shipyard that now decides to manufacture its own panelboards and lighting fixtures just for a particular vessel, may need a higher initial level of review to obtain that same level of confidence.

iii. The evaluator should look for the safety intent in referenced standards. Industry standards have evolved over many years, and for the most part, represent a national consensus by technical professionals of what is required to ensure that electrical equipment is safe. It is not easy to look at a standard, such as a UL standard and identify those requirements that are not related to safety. Nearly all requirements are safety related, either directly, such as by ensuring adequate dielectric strength or indirectly, such as by ensuring adequate mechanical strength so the equipment can safely withstand the rigors of installation and use. For equipment built to another standard, the evaluator should see if that standard adequately addresses the concerns addressed by the referenced standard.

Equipment evaluators should use the above guidelines in evaluating electrical equipment and in comparing it to the requirements of a referenced standard. To facilitate the review process, the following procedures may be used:

3.C.1.b(5)

(b) Standards Comparisons, Industry Standards. For equipment required to be constructed to an industry standard (domestic or foreign) and either listed by a nationally recognized (domestically or in the foreign nation) independent testing laboratory or certified by the manufacturer to be in compliance with the standard:

i. Manufacturer should submit evidence of listing (listing number in bill of materials, copy of listing card or documentation provided by the laboratory) or affidavit of compliance. The documentation should identify the specific construction and testing standard.

ii. Evaluators should establish that the foreign standard is complete, applicable and comparable to the referenced standard. (They may request a copy of the standard and/or that a standards comparison be submitted). This comparison may establish whether the overall level safety provided by the foreign standard is comparable to that provided by the referenced standard, including applicable marine supplements.

iii. For specific items for which comparability has not been established by comparing standards, such as would be the case if the foreign standard was for "land type" equipment and did not have requirements comparable to those in the marine supplement of a referenced UL standard, the manufacturer should submit documentation demonstrating compliance with the supplement requirements.

iv. Once standard comparability has been established for similar applications, no further comparisons need be requested on subsequent submittals using the same foreign standard. If the edition of either the referenced standard, as identified in the Finding Aids Section of the CFR, or of the foreign standard has changed, the specific changes need to be re-evaluated. To this end, the evaluators should maintain a listing of acceptable "equivalent" foreign standards, citing the specific editions compared. Additionally, the specific submitter should be encouraged to reference the acceptance letter in future submittals.

(c) Standards Comparisons, Not National Standards. For equipment not constructed to nationally (foreign or domestic) recognized standards:

i. The equipment manufacturer should submit a complete line-by-line comparison of actual construction and testing to that required by the reference standard, including any applicable marine supplement. Testing may be performed by the manufacturer. For those areas that are not in complete compliance with the reference standard, the manufacturer should submit technical

3.C.1.b(5)(c)

i. (cont'd) arguments for equivalency. These should be evaluated using the guidelines previously discussed.

ii. Once equipment comparability has been established, no further comparisons need be requested for that specific equipment from that specific manufacturer when equipment use is proposed on another vessel (again, this assumes the referenced edition has not changed). Listings should be maintained and notifications should be made in a manner similar to that used for standards comparability. The manufacturer should provide a copy of the acceptance letter with subsequent submittals.

iii. For issues that can be resolved based upon on-site visual examination, the evaluator may defer the acceptability of that equipment to the inspection activity (Officer-in-Charge, Marine Inspection or an authorized Classification Society acting on behalf of the Coast Guard in accordance with 46 CFR 8). In such cases, the specific issue deferred should be fully identified and documented. The inspection activity should also document the acceptance or rejection, and provide the plan review activity with inspection comments on deferred issues. The above procedure is for equipment required to meet a referenced standard. It should NOT be used for equipment required to be listed or labeled by an independent third party certification agency (i.e. fuses and equipment for use in hazardous locations). Note that the Marine Safety Manual Vol. II, B.5.E.4 permits the OCMI to accept on vessels of the Military Sealift Command, equipment or materials complying with any of the following: (1) technical bureaus of the U.S. Navy; (2) MILSPEC's; (3) federal specifications for military purchases, and; (4) National Military Establishment (NME) specifications.

c. Testing. Equipment that is to be type-approved must be tested in accordance with the applicable requirements of Subchapter Q. These tests shall be performed by an independent testing laboratory as defined in 46 CFR 159.010-3, or by the manufacturer and witnessed by a Coast Guard inspector.

2. Equipment Lists, COMDTINST M16714.3.

a. Introduction. Officially this is published in hardcopy as COMDTINST M16714.3; the latest printing was in May, 1994. The Office of Design and Engineering Standards, Commandant (G-MSE), publishes on-line USCG approved and certificated equipment list (available at: http://cgmix.uscg.mil/). This equipment list contains specific lifesaving, firefighting, pollution abatement, navigation, electrical, and miscellaneous equipment used aboard vessels that are required by certain navigation and vessel inspection laws and regulations to be of types that are approved or certified by the Commandant. Much of the equipment requiring review by Commandant can be located in subchapter Q of Title 46. Drawings and specifications for equipment are examined to advise manufacturers and prospective

3.C.2 a. (cont'd) purchasers whether such items when manufactured or installed will be acceptable for marine use. The need to have approved or certified equipment aboard a particular type of vessel depends upon the requirements of the laws and regulations applicable to that vessel. General authority over and responsibility for the administration and enforcement of the navigation and vessel inspection laws and regulations applicable to instruments, machines, and equipment used on vessels are vested in the USCG District Commander.

b. Application of Listings. The equipment list is an aid for persons desiring to install equipment of a type required to be approved or certified by the Commandant, and lists most of those items approved or certified by the Commandant. If an installed piece of equipment is not in the Equipment List Index that does not necessarily mean that such equipment must be replaced with that listed in the Equipment Lists. In connection with certain items, approval has been required by the regulations after certain dates, as set forth in the regulations. The equipment installed and in use on those dates are permitted to be retained in service so long as it remains in good and serviceable condition. When a previously approved piece of equipment is no longer serviceable, it must be replaced with currently approved equipment. The approval or certification of the items listed applies only to those specific items and does not extend to other devices or products that may be produced by the same manufacturer. The products listed under the various headings are not necessarily equivalent for a specific service and such listing indicates only that the minimum requirements of the statutes and regulations in effect at the date of the listing were met. If any of the items listed are found in the marketplace not to comply with the requirements of the statutes or regulations, such information, together with details regarding the deficiencies or defects believed to exist, should be brought to the attention of the cognizant District Commander.

c. Limitations of Listings. To keep outstanding approvals and certifications current, most are limited to a definite period of time. Most approved and certified instruments, machines, and equipment are limited to 5-year periods. If there have been no changes in Coast Guard requirements and the manufacturer is still producing the item without modification, an extension for an additional 5-year period is granted, provided the manufacturer requests an extension from Commandant (G-MSE). If the equipment is no longer produced and the certificate expires, the equipment continues to be considered certified based on the date of manufacture, the vessel installation date and a valid certification for that time period. Certification cannot be transferred to another manufacturer without Commandant (G-MSE) approval. Any modification to the design or construction requires review by the Coast Guard, and if approved the manufacturer will be issued a modified certificate. To identify equipment in this group further, those items that comply with Coast Guard specifications and regulations are assigned individual approval or certification numbers. For example 160.017/105/1 represents the 105th chain (embarkation) ladder approved for service and the certificate has been modified once.

d. Approvals Under Subchapter Q. Subchapter Q electrical equipment (see 46 CFR 161) is required to be "approved" by the Commandant and is

3.C.2 d. (cont'd) listed in the Equipment List Index. The following electrical equipment receives approval under Subchapter Q:

ELECTRICAL EQUIPMENT:

(1). 161.002 — Fire-Protective Equipment.
(2). 161.006 — Searchlights, Motor Lifeboat, for Merchant Vessels.
(3). 161.010 — Floating Electric Waterlights. Inspectors should continue to submit equipment failure reports on defective waterlights. However, quite often these lights have had their approvals superseded by new approvals. Waterlights that are approved at the time of installation and then have their approvals superseded may continue in service as long as they are operational.
(4). 161.011 — Emergency Position Indicating Radiobeacons.
(5). 161.012 — Personal Flotation Device Lights.
(6). 161.013 — Electric Distress Light for Boats.
(7). 165.101 — Magnetic Compass
(8). 165.102 — Transmitting Magnetic Heading Device (TMHD)
(9). 165.103 — Gyrocompass
(10). 165.105 — Speed and Distance Indicating Device
(11). 165.106 — Rate of Turn Indicator
(12). 165.107 — Echosounding Equipment
(13). 165.110 — Heading Control System
(14). 165.111 — Auto-Tracking Aid
(15). 165.112 — Track Control
(16). 165.120 — Automatic Radar Plotting Aid (ARPA)
(17). 165.121 — Electronic Plotting Aid
(18). 165.122 — Chart Facilities for Shipborne Radar
(19). 165.123 — Electronic Chart Display and Information System (ECDIS)
(20). 165.124 — ECDIS Back-up Equipment
(21). 165.125 — Raster Chart Display System (RCDS)
(22). 165.130 — Global Positioning System (GPS)
(23). 165.131 — Global Navigation Satellite System (GLONASS) Equipment
(24). 165.132 — Differential Global Position System (DGPS) Equipment
(25). 165.133 — Differential Global Navigation Satellite System (DGLONASS)Equipment
(26). 165.134 — Combined Global Position System and Global Navigation Satellite System (GPS/GLONASS) Receiver Equipment
(27). 165.135 — LORAN-C Equipment
(28). 165.136 — Chayka Equipment
(29). 165.140 — Integrated Bridge System
(30). 165.141 — Integrated Navigational System
(31). 165.150 — Voyage Date Recorder (VDR)
(32). 165.155 — Shipborne Automatic Identification System (AIS)
(33). 165.160 — Radar Reflector
(34). 165.165 — Sound Reception System
(35). 165.166 — Daylight Signaling Lamp
(36). 165.203 — Gyrocompass for High Speed Craft
(37). 165.210 — Automatic Steering Aid (automatic pilot) for High Speed Craft
(38). 165.251 — Night Vision Equipment for High Speed Craft

Part 162 of Subchapter Q lists the Engineering Equipment also requiring approval by the Commandant and is listed in the Equipment

3.C.2 d. (cont'd) List Index. The Marine Safety Center has been delegated the responsibility for the following engineering equipment approvals MECHANICAL EQUIPMENT:

(1). 162.017 — Pressure Vacuum Relief Valves for Tank Vessels
(2). 162.018 — Liquefied Compressed Gas Safety Relief Valves
(3). 162.050 — Pollution Prevention Equipment:
  (a) 15 ppm Oil-Water Separator (OWS)
  (b) Cargo Monitor
  (c) Bilge Monitor
  (d) Bilge Alarm

3. Engineering Applications for Pollution Prevention.

a. Marine Sanitation Devices (MSDs).

(1) Introduction. Type I, II and some type III MSD's receive certification by the MSC Engineering Division, Machinery Branch and listed in the on-line Equipment List Index and MISLE (available online at: http://cgmix.uscg.mil). Type III systems that operate at ambient temperature and pressures do not require approval nor will they receive a certificate or be labeled as Coast Guard approved. The MSC reviews the chemical processes and mechanical tests involved for compliance with 33 CFR 159. A Coast Guard accepted Independent Laboratory that has met the requirements of 46 CFR 159.010 must perform all tests required by 33 CFR 159. Typically, the application for an MSD is submitted to the MSC through the independent lab. A list of approved independent labs is available on-line at the Commandant (G-MSE-3) website. MSD systems installed aboard inspected vessels must also comply with 46 CFR, Subchapters F and J IAW 33 CFR 159.97. Subchapter F compliance involves design and fabrication requirements of the tanks, piping, valves, and appurtenances that are combined to make up an MSD system for use in inspected vessels. Specific individual acceptance by the MSC is possible for MSD systems not labeled for inspected vessels.

(2) MSD Tanks. Non-pressure vessel type tanks must be constructed of acceptable materials listed in 46 CFR 56.60 or equivalent materials, and vented in accordance with 56.50-85. Tanks with a MAWP exceeding 15 psig must be designed as pressure vessels in accordance with Section VIII, Division 1 of the ASME Code for Pressure Vessels, as amended by 46 CFR 54.

(3) Piping Systems. Piping systems and appurtenances associated with pressure vessels must be designed in accordance with the Code for Power Piping, ASME B31.1, as limited or modified by 46 CFR 56. Piping systems and appurtenances associated with non-pressure vessel-type tanks must be constructed of acceptable materials listed in 46 CFR 56.60-1 or 46 CFR 56.60-25, or shown to be equivalent. Polyvinyl chloride (PVC) is an acceptable material in MSD systems based on U.S. Navy Report #DINS Roc-78/041. This report basically states that methane gas is not produced in a combustible quantity in shipboard MSD systems. However, the process temperature and chemicals must also be considered in material selection.

3.C.3.a (4) Electrical Systems. MSD electrical systems are reviewed for compliance with Subchapter J. Overcurrent protection shall be provided in accordance with 46 CFR 111.50. Wiring shall be in accordance with 46 CFR 111.60. Motors shall be rated to the ambient temperature of the space in accordance with 46 CFR 111.01-15.

(5) MSD's prior to 1/30/76. MSDs made on or before 30 January 1976 were not process tested to the FWPCA requirements. These older plants, and some custom-built systems, may be certified under 33 CFR 159.12(c), by Coast Guard letter to the manufacturer or vessel owner. A copy of the letter should be kept aboard the vessel as evidence of compliance. These MSDs shall not be labeled under 33 CFR 159.15.

b. Oily Water Separators (OWS).

(1) Introduction. These devices are likewise approved by the MSC, which reviews such systems for compliance with 46 CFR 162.050 and lists the approved equipment in Equipment List Index. 46 CFR 162.050-21 requires OWS's to comply with Subchapters F and J. Subchapter F compliance involves design and fabrication requirements for the tanks, piping, valves, and other appurtenances that are combined to make up an OWS. To comply with Subchapters F and J, the following requirements must be met:

(2) Tanks. Non-pressure vessel-type tanks must be designed in accordance with 46 CFR 58.50-1 and vented in accordance with 46 CFR 56.50-85. Tanks with a MAWP exceeding 15 psig must be designed as pressure vessels in accordance with Section VIII, Division 1 of the ASME Code for Pressure Vessels, as amended by 46 CFR 54. However, ASME stamping of OWS's is not necessary. Filters, coalescers, and similar devices must meet the applicable requirements of 46 CFR 56.15-1.

(3) Piping. Piping systems and appurtenances must be designed in accordance with ASME B31.1, as limited or modified by 46 CFR Table 56.01-5(a). [NOTE: Most OWS's, monitors, and alarm piping will be treated as Class II piping (46 CFR Table 56.04-2).] Materials for piping appurtenances must be selected from the specifications given in Table 56.60-1(a) or Table 56.60-2(a), or other acceptable specifications listed in 46 CFR 56.60.

(4) Valves. Valves must be designed in accordance with the requirements in 46 CFR 56.20. Materials for valves must meet the specification requirements of 46 CFR 56.60-1.

(5) Electrical. Overcurrent protection shall be provided in accordance with 46 CFR 111.50. All wiring shall be in accordance with 46 CFR 111.60. Motors shall be rated to the ambient temperature of the space in accordance with 46 CFR 111.01—15.

c. Incinerators.

(1) Introduction. Shipboard incinerators are used to reduce waste volumes generated on board vessels, thus reducing the storage, handling and cost to dispose of waste. This includes victual

3.C.3.c (1) (cont'd) wastes, oily residues, dunnage, paper, packing materials and possibly sewage. The waste heat of some incinerators may in turn be used for boiler applications. Items that are not allowed to be burned are: Annex I, II, and III of MARPOL 73/78 cargo residues and related contaminated packing materials; Polychlorinated biphenyls (PCBs); garbage, as defined in Annex V of MARPOL 73/78, containing more than traces of heavy metals; and refined petroleum products containing halogen compounds. The U.S. is signatory to Annexes I, II, III and V.

Incinerators installed on or after March 26, 1998 must meet the requirements of IMO resolution MEPC.76(40) and an application must be type approved by the Marine Safety Center. Incinerators in compliance with ISO standard 13617, "Ships and Marine Technology-Shipboard Incinerators-Requirements," are considered to meet the requirements of IMO resolution MEPC.76(40). Incinerators in compliance with both ASTM F 1323, "Standard Specification for Shipboard Incinerators" and Annexes A1-A3 of IMO resolution MEPC.76(40) are considered to meet the requirements of IMO resolution MEPC.76(40).

(2) Testing by Independent Labs. Before type approval is granted the manufacturer shall have emission tests conducted, or submit evidence that such tests have been conducted by an independent laboratory acceptable to the Marine Safety Center, in accordance with the emissions annex in MEPC.76(40), that:

(a) Has the equipment and facilities for conducting the inspections and tests required by this section.
(b) Has experienced and qualified personnel to conduct the inspections and tests required by this section.
(c) Has documentation indicating the laboratory's qualifications to perform the inspections and tests required by this section.
(d) Is not owned or controlled by a manufacturer, supplier, or vendor of shipboard incinerators.

(3) Standards. The EPA has established emissions testing standards that are laid out in Appendix A of 40 CFR 60. Methods 1, 3A, 5, 9 and 10 o f Appendix A may be utilized by the laboratory in determining emissions related information described in Annex A1.5 of Resolution MEPC.76(40). Alternatively ISO standard 9096 (1992) "Stationary source emissions - Determination of concentration and mass flow rate of particulate material in gas-carrying ducts - Manual gravimetric method" maybe considered as an alternative to Method 5 and ISO standard 10396 (1993) "Stationary source emissions - Sampling for the automated determination of gas concentrations" may be used in lieu of Methods 3A and 10.

(4) Testing after installation. Incinerators, upon installation, should be tested in accordance with section 7.3 of MEPC.76(40). This section describes the various installation tests to ensure safe operation. Examples of some of the tests include fuel supply, flame safeguard and combustion controls.

(5) Operations and Training. All ships with approved incinerators must possess a manufacturer's operating manual specifying how to

3.C.3.c (5) (cont'd) operate the incinerator within the limits described in Annex A1.5 of Resolution MEPC.76(40). Personnel responsible for operation of any incinerator must be trained in its operation and capable of following the procedures and instruction in the manufacturer's operating manual.

d. Pressure-Vacuum Relief Valves.

(1) Introduction. PV valves are devices installed on board product carriers such as tank vessels and barges, which prevent over and under pressurization of a cargo tank as well as the passage of flame into or out of the tank. The PV valve is particularly valuable during cargo operations when the tank is most vulnerable to pressure changes and explosive atmosphere conditions. PV valves typically use weighted discs whose resistance must be overcome to relieve pressure or reduce vacuum. Flame screens of 30x30 or two 20x20 mesh spaced ½" to1.5" apart are also required unless the valve is considered "high velocity" where the escaping vapors must travel at a velocity no less than 30 m/s (99 ft/s) thus avoiding the explosive range.

(2) Design Requirements. These devices are reviewed for compliance by the Marine Safety Center using the standards in 46 CFR 162.017 or alternatively the IMO's Marine Safety Committee Circular 677 entitled "Revised standards for the design, testing and locating of devices to prevent the passage of flame into cargo tanks in tankers" as amended by Circular 1009 of June 8, 2001. Circular 677 references ISO standard 15364:2000 "Ships and marine technology - Pressure/vacuum valves for cargo tanks." A valve meeting the construction and performance testing standards of either the U.S. or IMO regulation, which are functionally equivalent, will receive a Certificate of Approval good for five years. Both foreign and domestic manufacturing firms can submit applications for certification of valves installed on board vessels operating within U.S. jurisdiction.

(3) Fire Safety. Ideally, when flammable cargoes are transported in a vessel cargo tank, the vapor that forms in the ullage space is either too rich to burn or it is inerted (oxygen deficient) and, therefore, unable to burn. In each case, the vapor concentration is maintained outside of the cargo's flammability range.

The maximum vacuum pressure that one would not want to exceed for fear of damaging (imploding) the cargo tank is covered in 33 CFR 154.814(b). Conversely, 46 CFR 39.20-11(a)(4) dictates a minimum vacuum pressure that is established to prevent air (oxygen) from entering a tank and creating a flammable atmosphere within the ullage space. Specifically the vacuum valve must not open until the vacuum drops below -0.5 psi. For example, a valve which opened at a vacuum of -0.4 psi would not meet the regulations. 46 CFR 39.10-1(a) states that the regulations for vapor control systems are written for vapors of crude oil, gasoline blends, and benzene. Consult Commandant (G-MSO-3) for issues involving systems handling vapors of other flammable cargoes.

3.C.4. Special Equipment Approvals.

a. General. Certain lifesaving equipment, electrical equipment, engineering equipment, pollution abatement equipment, and materials are required by law to be "Coast Guard approved" under specifications in 46 CFR, Subchapter Q. Once such equipment is approved, it is listed in the applicable subpart section of Equipment List Index, http://cgmix.uscg.mil/. The approval or certification of items listed applies only to those specific items, and does not extend to other devices or products that may be produced by the same manufacturer. Most approvals are limited to 5-year periods. Extensions for additional 5-year periods may be requested when there have been no changes to Coast Guard requirements and the manufacturer has made no modifications to the equipment. "Approved" equipment should not be confused with the eliminated Manufacturer’s Affidavit System, which listed acceptable manufacturers of valves, flanges, and fittings or with the list of acceptable hydraulic components. In 1989, this system was removed in favor of incorporating industry developed standards; see 54 FR 40598, October 2, 1989. (see Marine Safety Manual, Volume II, Materiel Inspection, COMDTINST M16000.7 (series))

b. Quick-Disconnect Couplings.

(1) Introduction. With new regulations concerning oil pollution prevention, the Engineering Branch was tasked with the review and granting of specific approvals for quick disconnect couplings (QDC's) (see 33 CFR 154.500-d(3) and 33 CFR 156.130-c(2)). Approvals granted before 19 July 1974 continue to be acceptable; however, revised or redesigned couplings must meet ASTM F-1122.

(2) Acceptance Procedures. In the past, QDC's plans and supporting data (calculations, test reports, material lists, etc.) were submitted to Commandant (G-MSE-3) for approval. QDCs no longer receive specific USCG equipment approval. QDCs must be designed, manufactured, tested and marked in accordance with ASTM F 1122, "Standard Specification for Quick Disconnect Couplings.”

c. Flame Barriers.

(1) Introduction. Coast Guard regulations require flame barriers in various venting applications. The two types required are flame screens and flame arresters. Applicable regulations for flame screens are found in Subchapter D (46 CFR 30.10-25 and 32.55), Subchapter F (46 CFR 56.50-85), and Subchapter T (46 CFR 450). Flame screens may not be used where the regulations require an approved flame arrester. Flame screens are approved by the OCMI. Flame arresters are required where a more effective flame barrier than a flame screen is needed. The type of vapor present determines whether an arrester is required. Approved flame arresters may be accepted in lieu of flame screens on an equivalency basis. Arresters that consist of a cellular, tubular, or baffle-type "grids" retained by a housing or flanges, are approved by Commandant (G-MSO-3) and are assigned approval numbers. Approval is based on review of design and on the result of performance testing. Installation of a flame arrester must not be permitted unless the device bears the Coast Guard approval number 162.016.

3.C.4.c (2) Design Requirements. Flame barriers are intended to prevent passage of flames outside a tank vent into the tank. They must be designed with openings too small to allow flame passage, but sufficiently large not to obstruct vapor flow. These devices should normally be mounted at the opening of the vent or vent stack. Barriers installed in the vent away from the opening may not be effective since the flame front will rapidly accelerate once it enters the pipe. The safety of installations with screens or arresters away from the opening should be demonstrated by suitable testing. Flame barriers should be durable, corrosion resistant, and have a low susceptibility to fouling. Careful periodic inspection and cleaning are very important. Screen type elements are only effective if they are undamaged by punctures or tears in the wire mesh, and there are no holes or gaps around the periphery larger than the openings specified for the 20x20 or 30x30 mesh screen.

d. Navigation Equipment.

(1) Design Requirements. The 2000 SOLAS (Safety of Life at Sea) amendments came into force on 01 July 2002. Regulations V/18.1 and 18.5 of these amendments require navigation equipment installed on ships to be type approved by the Administration. The regulations also call for the Administration to require manufacturers to produce approved navigation equipment under a quality system audited by a competent authority. Approval of Navigation Equipment for Ships, COMDTPUB P16700.4, NVIC 8-01 CH-1, describes the standards, regulations and processes for the approval of navigation equipment.

e. Resiliently Seated Valves.

(1) Introduction. RSV’s are valves that stop the passage of flow using resilient nonmetallic material instead of a metal-to-metal seat. Valves of this type must meet the specifications of 46 CFR 56.20-15. There are three categories, Positive shutoff, Category A, and Category B.

(2) Acceptable Locations. Positive shutoff valves are required in piping subject to an internal head pressure from a tank containing oil and must be located at the tank; see 46 CFR 56.50-60(d). Category A valves may be used in any location except where positive shutoff valves are required. Category A valves are required in the following locations:

(a) Valves at vital piping system manifolds;
(b) Isolation valves in cross-connects between two piping systems, at least one of which is a vital system, where failure of the valve in a fire would prevent the vital system(s) from functioning as designed; or
(c) Valves providing closure for any opening in the shell of the vessel.

Category B valves are not required to be tested and may be used in any location except where a Category A or positive shutoff valve is required.

3.C.4.e (3) Testing. Within these requirements, there are three possible ways for a manufacturer to certify that their valve is suitable for use as a Positive shutoff or Category A valve:

Pressure testing. The manufacturer must perform this test by removing all of the resilient material at testing full rated pressure and meet the flow requirements of 46CFR56.20-15 for either Positive shutoff or Category A as desired;

Calculation. Manufacturers may also demonstrate compliance through a method of calculation that is acceptable to Commandant (G-MSE-3) and are not limited to any particular calculation method to support their request for certification but are free to propose a method. For example, one method may be to use liquid capacity test data for valves of one size (with the resilient material removed) from a valve series to develop the flow coefficient for that valve size and then, following principles of dimensional similitude, scale up the flow coefficient for a valve of a different size (with the resilient material removed) within that same valve series. The liquid capacity test data could be obtained by maintaining constant pressure at the inlet side of the valve (with the resilient material removed) while adjusting pressure at the outlet side of the valve, then measuring the flow rate. Having calculated the flow coefficients for other valve sizes within the same valve series from the flow coefficient that was empirically derived from the liquid capacity test data, the flow rates for the other valves in the sizes within that valve series can then be calculated.

Fire testing. If a valve designer elects to use actual fire, Commandant (G-MSE-3) must accept the proposed calculation method or test plan, however the regulations do not specify any particular fire test that must be used. Some fire tests that may be acceptable include American Petroleum Institute (API) standard 607 “Fire Test for Soft Seated Quarter Turn Valves,” 4th Edition; API specification 6FA “Specification for Fire Test Valves”, 2nd Edition; or Factory Mutual Class 7440 that includes a cycling component in a fire test.

However, such tests would require that the valve be pressure tested at a pressure at least equal to the system pressure in which the valve would be utilized. Manufacturers are free to propose other fire tests to Commandant (G-MSE-3) for consideration in lieu of those mentioned above.

3.D. Vessel Inspection Alternatives.

1. References. Vessel inspection alternatives are discussed in Title 46, Code of Federal Regulations, Part 8. Additional information regarding the Alternate Compliance Program (ACP) is contained in the Marine Safety Manual, Volume II, Materiel Inspection, COMDTINST M16000.7 (series), Section B, Chapter 9. Additional information regarding the Streamlined Inspection Program (SIP) is contained in the Marine Safety Manual, Volume II, Materiel Inspection, COMDTINST M16000.7 (series), Section B, Chapter 10.

3.D 2. ACP Supplements. When a classification society applies to the Alternate Compliance Program a comparison is made between the classification society rules and the applicable sections of the CFR. Federal Register pages 7495 through 7499 of Volume 63, 13 February 1998, outlines the Critical Ship Safety Systems regulations that are reviewed in order to draft the supplement. When a classification society rules are used correctly in conjunction with the applicable supplement an equivalent level of safety as that provided by use of the CFR and SOLAS is provided.

Online: Supplements are available online and can be found by going to the Coast Guard homepage: http://www.uscg.mil. Once there, select "Marine Safety", then the "Marine Safety Index". Scroll down and select "G-MSE Office of Design & Engineering Standards". Under the Naval Architecture Division heading, select the "Alternate Compliance Program".

E. Mechanical Systems.

1. Engineering Materials.

a. Program Philosophy.

(1) Introduction. One phrase used throughout the vessel inspection regulations is "the component must be suitable for the intended service." A component's suitability depends upon a number of factors, one being the material from which it is made. In the design of a component, one of the most important considerations is the selection of material. This depends upon the physical shape and size of the component, its operating environment, useful life, and method of fabrication. The designer must match these design constraints to the mechanical and physical properties of the material and its behavior in the operating environment. These material properties are influenced by the chemical composition, the melting process, the method of forming, the method of fabrication, and any subsequent heat treatments. The infinite combination of these factors can make the material selection process very difficult. Fortunately, there are several standard organizations, such as the American Society for Testing and Materials (ASTM), ASME, and ANSI, that help make this selection process easier. The standards produced by these organizations place various constraints on the above factors, thereby ensuring consistent properties within a range for a given material over a period of time and among various producers. This consistency allows predictions to be made about the behavior of the material in various environments, so as to be able to place limitations on its use. For this reason, the Coast Guard usually accepts only materials that comply with one of these recognized standards. Not all standards are accepted. The consistency of the material's properties depends on the type of constraints used and how tightly these constraints are placed on the factors mentioned above. Another consideration is the amount of quality control required to ensure that the requirements have been met. Only standards that place adequate constraints and controls on the factors influencing the material's properties are accepted.

(2) General Acceptance Procedures. In general, the material specifications accepted specify the melting process, chemical

3.E.1.a (2) (cont'd) composition, mechanical requirements, and subsequent heat treatment necessary. These specifications also prescribe certain destructive and nondestructive tests to ensure that the material meets these chemical and mechanical requirements and that the material is free from injurious defects. In addition, a mill or manufacturer's certificate is required by most specifications and by regulations. The majority of the materials accepted are those listed in Sections I, III, or VIII of the ASME Code and ASTM specifications accepted by ASME B31.1.

(3) Fabrication Requirements. It is not enough, however, to know that a designer has selected one of the acceptable materials to ensure satisfactory service. Subsequent fabrication methods (e.g., severe cold work, forging, and welding) used in the manufacture of the component may substantially alter the material's properties. Therefore, to help ensure that these manufacturing operations are not detrimental, the Coast Guard has adopted certain industry standards (e.g., Sections I, III, and VIII of ASME B31.1) and regulations, which place limitations and requirements on these operations. These requirements are not all encompassing, especially for certain products such as valves. In addition, these requirements do not always provide adequate guidelines in the selection of the material for certain service constraints, such as corrosion. However, unless specific requirements prevent the desired application of a material, the Coast Guard does not restrict the designer's selection (i.e., the adequacy of the choice will usually not be addressed).

(4) Headquarters Action. Commandant (G-MSE-3) is responsible for determining which materials are generally acceptable for boilers, pressure vessels, and piping systems and any limitations on their use; providing guidance to the field on the acceptance of other materials that are not generally accepted; and participating on national technical committees to develop material standards that meet USCG requirements for quality control and certification.

(5) Field Technical and Inspection Action. MSC personnel are responsible for determining that the material selected for a component meets Coast Guard requirements and is suitable for its intended purpose. This requires the reviewer to exercise considerable judgment when specific guidelines or standards are not provided. For this reason, the reviewer should become familiar with the basic materials used and their limitations. The reviewer must recognize that the suitability of a material not only depends on how it reacts in a given environment, but also how it reacts to certain fabrication methods and design details. Inspectors must ensure that only approved materials are used, and the fabricator adheres to the approved drawings and applicable standards, such as the ASME Code.

b. Evaluation Of Materials.

(1) Certification. 46 CFR 50.25 requires the certification of material, depending on the product, by the following methods:
(a) A manufacturer or mill certificate;
(b) An affidavit; and
(c) Specific letter and approved plan.

3.E.1.b (1) (cont'd) A manufacturer's or mill certificate is required for such products as plates, castings, forgings, bar stock, bolting, piping and tubing, and standard pipe joining fittings. This certificate is used to verify that the material complies with the basic requirements of a material specification and any supplementary requirements specified on the order. The certificate, as a minimum, shall report for each heat or lot the material specification and grade to which the material complies, along with the chemical analysis, mechanical properties, and any heat treatments to which the material was subjected.

(2) Testing. The material specifications accepted require certain tests to be performed to ensure that the material has the desired properties. These tests depend on the type of product and its expected service. Most material specifications accepted require a chemical analysis and tension test. Other tests that may be required include:

(a) Impact tests for materials used in low temperature service;
(b) Bend tests for plates;
(c) Flattening tests for pipes;
(d) Certain nondestructive tests for castings and welded pipes;
(e) Hardness testing for heat treated materials; and
(f) Certain chemical tests to determine the material's susceptibility to corrosion.

When called out in the basic portion of the material specification, these tests must be performed on all heats of materials produced. It is interesting to note that the only things that may separate one material specification from another are the types of basic tests required (e.g., ASTM A576 and A675).

Most material specifications provide for tests in addition to those required in the basic specification. These supplemental tests may be required by the purchaser to ensure that the material has certain properties required for a specific application (e.g., low or high temperature service). The buyer must purchase a sufficient quantity of material (usually a mill run) to have the mill perform the tests and guarantee that the material will have the desired properties. This is done because the mill may have to use different melting practices, tighter controls on certain elements, etc., to meet the additional test requirements with greater confidence. For this reason, it is difficult to require a manufacturer to purchase material with supplemental test requirements. The reviewer should take this into account prior to making such a request.

(3) ASTM and ASME Specifications. The majority of material standards are developed by the ASTM. The ASTM has thousands of standard specifications in effect. These standards are published in a multi-volume set known as the Book of ASTM Standards. A great many of the ASTM standards are reprinted or specified by various building codes such as the ASME Code, which adopts many of the ASTM standards without changes. However, some ASTM standards are adopted with minor to major changes. These changes usually

3.E.1.b (3) (cont'd) involve the requirement for a material certification, the deletion of certain melting practices, changes in lot size, deletion of certain grades, etc. The ASME material standards are published in Section II of the code. Section II contains three parts: Part A - Ferrous Materials; Part B -Nonferrous Materials; and Part C - Welding Rods, Electrodes, and Filler Metals. Appendix B of Section VIII, Division 1 of the ASME Code outlines the code policy for approval of new materials. To facilitate identification, the material designations used by ASME are similar to those used by ASTM (e.g., ASME SA516 and ASTM A516 are similar materials).

(4) Equivalencies. 46 CFR 50.20-30 and 56.60-1(a)(2) permit materials other than those generally accepted to be used, provided they receive specific approval of the Commandant. This authority has been delegated to the MSC in the course of plan review. The task of determining the suitability of a material for a specific application is difficult. The task of determining the suitability of a material for a specific application material involves comparing the material with one that is generally accepted to get as close a match as possible. The differences are then analyzed for their relative importance to the specific application. If they are considered to be substantial, the material is either rejected or accepted with the provision that the requirements of the generally accepted material are met. The following is a list of some of the items that should be considered:

(a) Chemical requirements;
(b) Mechanical requirements, including location and configuration of the test specimens;
(c) Melting practices;
(d) Heat treatments;
(e) Quality control provisions;
(f) Fabrication processes;
(g) Design margin; and
(h) Directions of principal stresses, especially for plates.

[NOTE: These items are so interrelated that it is impossible to provide specific guidelines for their consideration.]

(5) Foreign Specifications. The majority of foreign material specifications reviewed for equivalency are Japanese Industrial Standards (JIS), British Standards (BS), and Deutsches Institute fur Normung e.v. (DIN). In general, the basic format of these specifications is similar to that of ASTM standards. Other than obvious differences in chemical and mechanical requirements, the reviewer must be careful to note the differences in test specimen size and other quality control provisions; for instance, in JIS 3101, the percent elongation for plates less than 5mm thick is based on a test specimen that has no ASTM equivalent. The JIS specimen with its shorter gauge length (50mm) would measure a higher percent elongation for the same thickness than the 200mm gauge length ASTM specimen. However, the JIS specimen's smaller width (25mm) and, therefore, smaller cross sectional area would measure a smaller percent elongation than the 40mm wide ASTM specimen.

3.E.1 c. High Temperature Service Materials.

(1) Introduction. When selecting materials for elevated temperature service, such factors as creep and stress rupture, fatigue, surface oxidation, structural changes within the material, and corrosion must be considered. Among these, creep and stress rupture represent two of the more important factors. Creep is defined as the time-dependent part of deformation that accompanies the application of a constant load. Usually, it is expressed as a deformation rate (e.g., 1 percent in 100,000 hours). Stress rupture is defined as the stress required to produce fracture in a specified time at a given temperature.

(a) Creep and Stress Rupture Properties. Creep and stress rupture properties are considerably influenced by the metallurgical characteristics of the material and the testing and service environments to which it is exposed. The most important metallurgical characteristics of the material are chemical composition, structure, and grain size, which are primarily controlled by prior processing and heat treatment. Composition is the most important variable. Improvements in creep and stress rupture properties by alloying additions generally may be related either to the amount and size of fine particles that are distributed within the structure of the metal, or to a general strengthening effect of the overall (matrix) structure without the formation of such particles. As a note of caution, the mere addition of alloying elements does not ensure higher creep and stress-to-rupture properties. The effect of grain size on these properties is related to the equicohesive temperature of the material. The equicohesive temperature (usually between 800 and 1000°F for low-alloy steels) is the temperature at which the grain strength is equal to the strength of the material at the grain boundaries. At temperatures above the equicohesive temperature, coarse-grained steels generally exhibit better creep and stress-to-rupture properties than do fine—grained steels. Below the equicohesive temperature, the trend reverses.

(b) Heat Treatments. Heat treatments are important primarily because of their effects on the structure of the metal. Heat treatment and cooling rates will affect the grain size of the material and the distribution of the structural constituents. A normalized and tempered steel is often superior to the same steel in the fully annealed condition. When heat-treated steels are employed at elevated temperatures, it is customary to use a tempering temperature at least 150°F above the expected service temperature. The heat treating temperature and cooling rate are very critical. A change of only a few degrees can cause a considerable difference in the microstructure of the material, which will result in a different resistance to creep. For this reason, the ability of the furnace to maintain a uniform temperature and the method of cooling to ensure a constant rate throughout the material are critical. This becomes more important as the size and thickness of the part increase. The relatively

3.E.1.c(1) (b) (cont'd) conservative safety factors applied on design help to offset these possible differences.

(2) Considerations for Prolonged High—Temperature Exposure. Just as heat treatment affects the microstructure of the material, so does prolonged exposure at high temperatures. When steels are exposed to temperatures above 800°F, some changes may take place in the microstructure. The higher the temperature, the more rapid the rates at which the changes occur. In low-carbon steels that have been normalized or annealed, the carbide gradually changes to the spherical form upon prolonged heating above 900°F. Chromium tends to delay this spheroidization until higher temperatures are reached. Some carbon steels and carbon-molybdenum steels are prone to graphitization when exposed to temperatures over 775°F. Primarily susceptible have been fine-grained aluminum-killed steels. Cast irons are also prone to graphitization. When it occurs in steels, graphite formation has been most pronounced in the heat—affected zones parallel to welds. High concentrations of graphite in these zones have caused severe embrittlement. [NOTE: 46 CFR 56.60-5(d) limits the maximum temperature for these steels to below the lowest graphitization temperature.] Another form of metallurgical instability involving carbon occurs in some types of austenitic stainless steels. When these steels are exposed, during fabrication or in service, to a temperature between 900 and 1500°F the carbon diffuses to the grain boundaries and combines with chromium to form chromium carbide particles. This instability is referred to as intergranular carbide precipitation and it reduces the resistance of the stainless steel to certain corrosive solutions

(3) Applications To Particular Materials.

(a) Steel. Carbon steels generally are not used at temperatures over 775°F. The 1/2% Mo steels are used as tubing in superheaters to about 850°F. The 1-1/4Cr - 1/2Mo steels are used in steam piping and boiler tubes for service up to 950 or 1000°F. The 2 - 1/4Cr - 1Mo grades are used in steam power service to temperatures of about 1060°F. They exhibit slightly better oxidation resistance than the 1- 1/4Cr-1/2Mo grades. The 5Cr - 1/2Mo, 7Cr - 1/2Mo, and 9Cr - 1Mo grades are used where better oxidation and corrosion resistance are required, at temperatures up to 1500°F.

(b) Stainless Steels. Among the martensitic stainless steels, Type 410 alloy is used where good strength is required at temperatures up to about 950°F. Among the ferritic stainless steels, Type 430 is used in heat exchangers, condensers, and special chemical applications. Among the austenitic stainless steels, Type 316 is generally superior to other commercial stainless steel grades and is used at temperatures up to 1050-1200°F. Type 304 exhibits good resistance to atmospheric corrosion and oxidation. Types 309 and 310 exhibit still greater resistance to oxidation because of their higher chromium and nickel contents. Type 310 is particularly preferred where intermittent heating and cooling are encountered since it forms a more adherent scale than

3.E.1.c(3) (b) (cont'd) does Type 309. For high-temperature service, tube materials frequently receive special solution heat treatments to provide a coarse grain size resulting in improved creep strength properties. Stainless materials so heat treated are designated as "H" grades, such as TP321 H. A number of special high—alloy austenitic stainless steel compositions have also been developed for high—temperature service. They generally contain higher nickel compositions than those of the ordinary austenitic stainless steels. These include Incoloy, Incoloy T, and Kromarc-58.

(c) Cast Gray Iron. Ordinary cast irons are limited for elevated temperature applications, due to the breakdown of carbides and growth of the component. This growth is a permanent increase in volume that occurs under certain conditions of heating and cooling; it is independent of stress. It is affected by the presence of superheated steam and certain corrosive fluids. In severe cases of growth, the volume may increase as much as 50 percent, with an attendant loss of strength and development of brittleness. High-alloy cast irons containing 14 percent nickel with additions of copper, chromium, or silicon have been developed; these resist growth and oxidation at temperatures up to 1500°F.

(d) High—Nickel Alloys. The temperature limits for the nickel and the ordinary nickel alloys are approximately 800 to 1000°F. Nickel, Monel (70 percent nickel, 30 percent copper) and numerous copper-nickel alloys (60 to 70 percent copper, 30 to 40 percent nickel) have been developed for valve trim and miscellaneous accessories handling steam.

(e) Copper and Copper Alloys. The use of copper and copper alloys for elevated temperatures is limited to temperatures below the lower recrystallization temperature for the particular alloy. This is the temperature at which cold—worked specimens begin to soften. Brasses containing 70 percent or more copper may be used at temperatures up to 400°F, while those containing only 60 percent of copper should not be used at temperatures over 300°F.

d. Low—Temperature Service Materials.

(1) Introduction. 46 CFR 54.25-10 defines low-temperature service as refrigerated service below 0°F. "Refrigerated service" is defined as service where the temperature is controlled in the process rather than being caused by atmospheric conditions. This temperature limit also applies to piping (see 46 CFR 56.50-105). Unexpected and sudden failures in piping, pressure vessels, and other structures, such as welded steel ships, have made engineers aware that some materials, especially steel, that behave ordinarily in a ductile manner may, under these three certain conditions, exhibit highly brittle characteristics:

(a) High stress concentrations (i.e., notches, internal flaws, or sharp changes in geometry);
(b) A high rate of straining; and
(c) A low ambient temperature.

3.E.1.d (2) Effects Upon Materials. The general effect of decreasing the exposure temperature is to increase the yield and tensile strengths of all structural alloys. However, the allowable stresses for materials used at low temperatures are usually based on room low service temperatures. [NOTE: 46 CFR 54.05-30 provides for an increase in allowable stress values at low temperature in ferrous and nonferrous material.] The effect of low temperatures on the elongation and reduction in area are variable depending on the alloy and testing temperature. The effect on ductility is most pronounced in steels. As the temperature is lowered from some high value, the ductility of steels decreases slowly until a certain temperature is reached. At this temperature the ductility falls off sharply. This continues until another temperature, known as the transition temperature, is obtained. Below this temperature ductility remains constant, or nearly so, as the temperature is lowered. The transition temperature is the temperature above which the steel behaves in a predominantly ductile manner and below which it behaves in a predominantly brittle manner. There is no singular transition temperature except for a particular set of conditions and one criterion of brittleness.

(3) Methods of Testing. Several testing methods have been developed for determining the notch toughness and crack toughness of structural alloys at low temperatures. The most common is the Charpy V-notch impact test (see ASTM A370). Several criteria are used to designate the transition temperature based on the results of a Charpy V-notch test. These are:

(a) The energy level absorbed, usually taken as 15 ft-lb;
(b) The percentage of ductile fracture in the fractured surfaces, usually 50 percent; and
(c) The amount of lateral expansion. Other methods are the precracked Charpy specimens, drop weight tear test specimens, and specimens for determining the nil-ductility transition (NDT) temperatures (see ASTM E208).

These procedures are basically qualitative, in that they can be used to compare one alloy against another. There is no quantitative relationship between the transition temperature and a safe minimum service temperature for a given alloy. Even so, standards based on these methods have been applied with definite success to minimize the occurrence of brittle fracture. A more quantitative type of fracture test is that produced under plane-strain conditions to obtain data on plane-strain stress intensity factors according to principles of fracture mechanics (see ASTM E399). The important factor of these tests is that the critical sizes of cracks and flaws may be estimated for a given service temperature and maximum service stress level based on the results of these crack-toughness tests (KIc values). 46 CFR 54.05 states the requirements for toughness tests of materials used in pressure vessels. This section requires either the Charpy V-notch or drop-weight test.

(4) Applications To Particular Materials.
(a) Steel. Metallurgical factors, such as deoxidation practice, chemical composition, rolling, forging or extruding practice,

3.E.1.d(4) (a) (cont'd) and subsequent heat treatment influence the transition temperature in steel. Under the worst conditions, the transition temperature may be above 100°F; under the best conditions, below -200°F. Fully killed (deoxidized) steels have lower transition temperatures than rimmed or semikilled steels. Such steels are sometimes referred to as being made in accordance with fine-grain melting practice. Carbon influences the transition temperature unfavorably, and is usually limited to 20-25 percent. High ratios of manganese to carbon may be beneficial. Other elements usually raise the transition temperature, with the notable exception of nickel. Steels that have been fully annealed have higher transition temperatures than those that are normalized. Tempering or stress relieving after welding is beneficial to lowering the transition temperature. Optimum properties are obtained by fully quenching and tempering to moderate strength levels. The minimum recommended service temperatures and special requirements for steel are specified in 46 CFR 54.25-10, 54.25-15, 54.25-20, and 56.50-105.

(b) Aluminum Alloys. Fracture toughness of most of the aluminum alloys in the 2000, 5000, and 7000 series is not significantly affected as the temperature is lowered. This, and the fact that the yield and tensile strengths increase as the temperature is lowered, makes these alloys good candidates for low temperature applications. Aluminum alloy 2219-T87 has a good balance of strength, toughness, and weldability. Alloy 5083-H113 is used where toughness and weld ability are of prime importance. For even greater toughness (e.g., for LNG tanks), 5083-0 alloy plate is used.

(c) Copper and Copper Alloys. These alloys tend to increase in strength as the temperature is lowered and retain their ductility. These alloys are generally not used in cryogenic equipment, except for accessories such as tank gauges, but are used extensively in refrigeration and liquefying equipment.

(d) Nickel—Base Alloys. These alloys exhibit increased strength and retain their ductility as the temperature is lowered. Invar, a 36% nickel-63% iron alloy, is used in Gas Transport LNG tanks because of its extremely low coefficient of expansion (0.0000004 per degree Centigrade).

e. Corrosion.

(1) Introduction. One factor that must be considered in the design of equipment is corrosion. This is especially true for equipment used in the marine environment. This subject is quite varied and complex and, therefore, can be discussed only in general terms. For this reason, the Coast Guard has few specific rules concerning corrosion. The basic types of corrosion fall into two categories: corrosion due to direct chemical attack, and corrosion due to electrochemical attack, which requires the presence of an electrolyte; seawater is the most common electrolyte encountered aboard ship. The basic types of corrosion are described below.

3.E.1.e (2) Regulatory Requirements.

(a) 46 CFR 54.01-35 requires pressure vessels to have a corrosion allowance of one-sixth of the required thickness or one-sixteenth of an inch, whichever is less. An exemption from this requirement may be granted if the pressure vessel is adequately protected from corrosion. [NOTE: Paint is not considered to provide adequate protection from corrosion. Also, when determining the corrosion allowance for pressure vessels made from pipe, the mill tolerance on the pipe wall thickness should be considered.]

(b) 46 CFR 56.60-3(a) requires ferrous pipe used for salt water service to be galvanized or be of extra heavy-schedule material.

(c) 46 CFR 56.60-20 cautions against the possibility of galvanic corrosion when using copper and aluminum alloys in conjunction with each other or steel. This section further points out the poor corrosion resistance of aluminum alloys with copper contents exceeding 0.6 percent. This is due to the fact that precipitation of the aluminum-copper constituent at the grain boundaries leaves the adjacent solid solution anodic. These depleted zones, being the most anodic, corrode selectively by an electrochemical process, producing notches or crevices that become stress raisers.

(d) Footnotes 7 and 9 of 46 CFR Table 56.60-2(a) require an ammonia vapor test for certain copper alloys. This test is used for the purpose of detecting the presence of residual (internal) stresses that contribute to stress-corrosion cracking of these materials.

(e) Footnotes to 46 CFR Table 58.50-10(a) prohibit galvanizing the interior of diesel fuel tanks. This is because diesel fuel reacts with the zinc to form a sludge, which can clog the fuel system (this is not true of gasoline).

(3) Galvanic Corrosion. Galvanic corrosion occurs when two dissimilar metals are electrically coupled in the presence of an electrolyte, such as seawater. Current will flow through the electrolyte from the anodic material to the cathodic material, thus causing accelerated corrosion of the anodic material. Marine Engineering, published by the Society of Naval Architects and Marine Engineers (SNAME), contains a listing of metals in seawater, arranged in approximate order from the most anodic in behavior (magnesium alloys) to the most cathodic in behavior (graphitized cast iron).

The suitability of a dissimilar metal couple in practice may depend on the relative areas of the anode and cathode. If the anode is small relative to the cathode, the anode may suffer a rapid rate of deterioration. However, if the cathode is small relative to the anode, the corrosion and average penetration rate of the anode may remain at a tolerable level. It may be possible to reduce corrosion of the anode with paint. However, the paint

3.E.1.e (3) (cont'd) should be applied to the cathode, not the anode. This is because any imperfection in the paint, if applied to the anode, would result in an even more unfavorable cathode/anode area ratio. For the same reason, care should be exercised when applying noble metal coatings on a less noble base metal (e.g. chrome plate on carbon steel). If the coating contains any imperfection, the large cathode to anode area ratio can cause severe corrosion of the base metal in the localized region of the imperfection.

(4) Pitting Corrosion. This form of galvanic corrosion occurs as the result of local cells that develop on the surface of a single material. These cells arise from local environmental differences. Aluminum alloys with heavy metal alloying elements, such as copper, nickel, and iron, are subject to severe pitting. This results from the anodic behavior of the aluminum matrix and the cathodic behavior of the heavy metal alloying elements. Metals that form a protective oxide film, such as the stainless steels, are highly susceptible to pitting. These, more so than carbon steels, pit greatly because any local breakdown of the film exposes a local active area of less noble character.

(5) Intergranular and Selective Phase Corrosion. This type of corrosion is due to heterogeneities in the metal that result in preferential corrosion of one of the components of the alloy. Several examples of this type are:

(a) Intergranular corrosion of austenitic stainless steels as the result of carbide precipitation at the grain boundaries;
(b) Dezincification of brass and bronze containing more than 15 percent zinc; and
(c) Dealuminization of some aluminum bronzes in which the aluminum-rich gamma phase is selectively attacked.

(6) Stress Corrosion. Stress corrosion is a form of local deterioration resulting from the combined action of static stress and corrosion, which leads to cracking of alloys. This corrosion only occurs in the presence of tensile stresses, which may be applied and/or residual. Stress corrosion of a particular material usually occurs only in specific environments, which may be only mildly corrosive in the absence of stress. Steels produced to a yield strength in excess of 150,000 psig are susceptible to stress corrosion in a marine environment. Many aluminum alloys in the 2000 to 7000 series are susceptible to stress corrosion in seawater.

f. Use Of Stainless Steel Materials.

(1) Introduction. Stainless steels develop a thin oxide layer that protects the metal from surface corrosion. The development of this protective film is known as passivating. Some authors define chromium-nickel steel as "stainless" if it contains as little as 10 percent chrome; others regard 11.5 percent chrome as the minimum possible amount for passivating to occur. Chlorides dissolve this passivating film. However, if ample oxygen is available, the oxide film restores itself as fast as it is broken down, and the surface remains protected. At any location where

3.E.1.f (1) (cont'd) oxygen is kept out, deep pitting may occur because the chlorides destroy the passive film and the spot becomes active. Active and passive spots on the same piece of stainless steel can be so galvanically different as to cause rapid deep pitting. Once a pit starts, it serves as an active spot where the chloride reaction products themselves keep the oxygen out and corrosion can continue. Stainless steel parts in stagnant saline water, located in such places as low points in piping where water accumulates or fuel tanks in bilges of small boats, may be subject to this type of concentrated and rapid pitting attack. Even when the surfaces are exposed to ample oxygen, crevices may become stagnant or fouled areas and, therefore, active pits may develop. Susceptibility to chloride action can be greatly reduced (although not totally eliminated) in several ways:

(a) By increasing the chromium content to 25 percent and the nickel content to 20 percent, rather than the common 18 percent and 8 percent mixes;

(b) By the addition of 2-3 percent molybdenum (316 and 316L);

(c) By decreasing the carbon content (304, 304L, 316L);

(d) By selecting chromium and nickel equivalents to keep more austenite and less ferrite in the metal. For equivalents and percentage of ferrites, see the Schaeffler diagram, Figure 65.5, of the AWS Welding Handbook, Volume 4 (6th ed.). However, some of the desirable corrosion-resisting additives also promote ferrite formation; or

(e) By avoiding sulfur and selenium, which are sometimes added to enhance free—machining properties.

(2) Extra—Chloride Corrosive Effects. In addition to pitting at any random point in the material as described above, pitting in the grain boundaries, intergranular corrosion, and stress corrosion cracking can occur. The same chloride attack is contributory, but these types of corrosion occur in the grain boundaries due to a depletion of chrome or a buildup of carbon, thus negating the benefits indicated in items (2) and (3) above. This effect can be reduced by:

(a) Not allowing the material to remain any longer than necessary at temperatures between 350 and 927°C (662-1700°F), or, if this has already occurred, by heat treating the material above 1010°C (1850°F) and quickly cooling. (See UHA-100 through 108 of Section VIII, Division 1 of the ASME Code.)

(b) Avoiding the edges of as-rolled plate. Rolling orients the grains in such a way that those grain boundaries perpendicular to the edge corrode more rapidly. Pit nuclei, therefore, exist at the edges of sheets, and fresh-cut edges are less likely to have active pits already started.

(c) Avoiding cold-working and hot-working. Such areas are likely to have intergranular problems somewhere within or adjacent

3.E.1.f(2) (c) (cont'd) to the affected area, unless the cold or hot-working is followed by heat treating as in (1) above.

(d) Adding titanium or columbium. For this purpose, there should be four to six times as much titanium, or eight to ten times as much columbium, as carbon. In welding electrodes, columbium is preferable to titanium.

(3) Consideration In The Use Of Stainless Steels.

(a) Introduction. From the above discussion, it is clear that stainless steel is not always "stainless" and should not always be considered a suitable substitute for carbon steel. For this reason, the reader is cautioned that the term "steel," when used in the regulations, may not include "stainless steel." For example, 46 CFR Table 58.50-5 lists "steel" as an acceptable material for independent fuel tanks. However, Note 4 requires that the "steel" be galvanized. Thus, "stainless steel" is not included in the general term "steel," and its use must be specifically approved. Although one specific material such as properly heat treated 316L is likely to be clearly best, the Coast Guard often must decide whether something less than the best is acceptable or unacceptable in a particular application.

(b) Certification by a Metallurgist. Engineers will differ as to where to draw the line between acceptable and unacceptable. If a material manufacturer's metallurgist, who is familiar with marine applications, certifies that the proposed material, design, welding, heat treatment and other pertinent details are an acceptable combination in the proposed location and service, this will generally be acceptable. A greater degree of documentation or testing may be required in new applications in vital or hazardous services. A lesser degree of information will often be acceptable in many routine applications.

(c) Restrictions in "Freshwater" Service. The pitting problem should not be disregarded for non—ocean service. Chloride ions exist in sufficient quantity to pit some stainless steels in many waters normally regarded as "fresh." Natural minerals, road salt runoff, industrial and agricultural pollutants, and brackish water in estuaries can all contribute chlorides in sufficient quantities to cause active pitting in the absence of ample oxygen for passivating. Also, evaporation will increase the chloride concentrations in bilges, crevices, and similar locations. Stainless steels should, therefore, generally not be accepted in stagnant water services, such as boat tanks located in bilges and other wet, unventilated areas. In dry, well-ventilated areas (such as the upper levels of engine rooms), the better marine alloys may be used without coatings and with reasonable control of crevices and cleanliness.

(d) Restrictions In Deck Equipment. On deck, the better marine alloys may be used without coatings, but with every effort to minimize crevices. Inspectors should be aware that such

3.E.1.f(3) (d) (cont'd) items as LNG piping (which is generally made from such materials as 304L stainless steel, for other reasons) should be carefully examined for crevice corrosion around gaskets, at the edges of insulation where imperfect sealing may allow salt to collect, etc. [NOTE: Listing of an alloy in 46 CFR 56.50-105 as "acceptable for cryogenic piping" does not imply that it is acceptable in all locations aboard ship.]

(e) Restrictions Against Coatings. Coatings, which have been accepted for stainless steel boat fuel tanks under a previous policy, are a less desirable solution. Slight damage to coatings, such as peeling, cracking, etc., can concentrate pitting at the point of damage. Coatings may hide perforations of the metal due to internal pitting, which may occur when saline water gets into fuel tanks, until fire damage to the coating reveals that the supposedly fire-resistant stainless steel has been holed. In most cases, the use of stainless steels should be accepted without coating or prohibited. Only in special cases, as when a boat with existing stainless fuel tanks comes into inspected service, should acceptance of a coating be considered; acceptance in such cases should be limited to tanks that can be readily inspected inside and out.

(f) Use In Vessel Tanks. Because chloride pitting can completely hole a thin tank between required Coast Guard inspections, stainless steel tanks should be required to be no thinner than carbon steel tanks, in accordance with the tables in 46 CFR 58.50, and 182.440(A)(1), if permitted at all.

(g) Summary. All of the information above concerns normal and low temperature service. Chloride pitting becomes more severe very rapidly at high temperatures. In some alloys, this transition may occur at as low as 125°F. Different alloys may be better for hot, fast-flowing saltwater service such as cooling water discharges. Such special applications must be considered individually. The sources cited below do not show any actual data for corrosion at cryogenic temperatures, but the corrosion rate curves available seem quite flat throughout the ambient temperature ranges. Therefore, corrosion is likely to be the same or lower at very low temperatures, and should be evaluated at ambient temperatures unless data showing a significant reduction is submitted.

(4) Additional Information. Further information may be obtained through the following sources:

(a) Marine Corrosion: Causes And Prevention, Francis L. LaQue; Wiley, New York, 1975.

(b) The Corrosion Handbook, H.H. Uhlig, Ed.; Wiley, New York, 1948.

(c) Corrosion (2nd Ed.), Volumes 1 and 2, L. Shreir, Ed.; Newnes— Butterworths, London, 1976.

3.E.1.f(4) (d) Corrosion And Its Prevention In Waters, G. Butler and H.C.K. Ison; Reinhold, New York, 1966.

(e) UL Assignments 65WW32 & 65WW63, "Environmental Exposure Of Sample Model Marine Fuel Tanks," Files MM—36 & MM—10, Final Report Yacht Safety Bureau (YSB) R6—l—0469.

2. Boilers, Pressure Vessels, And Similar Equipment.

a. General Provisions.

(1) Introduction. Throughout the regulations concerning Coast Guard certificated vessels, it is common practice to refer to the Marine Engineering Regulations (46 CFR, Subchapter F) for general requirements for pressure vessels, boilers, thermal fluid heaters (TFHs), and similar equipment. It should be recognized, however, that some special types of pressure containing equipment, such as hazardous cargo tanks, pressure vessels for human occupancy (PVHO's), etc. are partially or completely outside the scope of Subchapter F. Requirements consist basically of industry safety codes and standards, with the bulk of the regulations addressing changes or modifications to bring these requirements in line with good marine practice. Because of our adoption of industry codes and standards, our committee participation is quite meaningful. Equipment repairs should meet requirements comparable to those for new equipment. Unless equipment is accepted as part of an existing ship being brought under Coast Guard certification for the first time, the regulations do not presently provide for acceptance of existing equipment. The provisions of 46 CFR 50.05-5 regarding existing boilers, pressure vessels, or piping systems apply only to equipment that was accepted by the Coast Guard when new, but which has deteriorated in service or has been out of service for some time.

(2) Approval Process. All boilers and TFHs are reviewed by the Marine Safety Center (MSC), with copies of the reviewed plans sent to the cognizant OCMI. The ASME stamp has been adopted for power and heating boilers in lieu of the Coast Guard plan approval and shop inspection that occurred prior to final rules issued on 8 March 1985. The final rules also require safety valves used on boilers to meet the ASME Code, and eliminate the requirement that they be Coast Guard approved. These regulations apply to propulsion boilers, auxiliary boilers, fired thermal fluid heaters, exhaust gas boilers, heating boilers, hot water supply boilers, and certain unfired steam boilers.

(3) Functions Of Boilers. A boiler is a unit that produces steam or high-temperature water for use external to itself. Steam boilers always produce a phase change by heating. Evaporators differ from unfired steam boilers in that they generate steam for distillation purposes. Unfired steam boilers produce steam from an external heat source (such as engine exhaust) to supply steam for some function such as heating, doing work, or removing water from oil. Hot water supply boilers supply water that is not returned to the boiler or otherwise retained. Hot water heating boilers usually produce hot water to use in a heating operation,

3.E.2.a (3) (cont'd) after which the water is normally returned to the boiler. Not fully understanding these differences has resulted in misapplication of regulations in the past.

(4) Historical Development. Although boilers have been used in marine industry for a long time, developments in marine boiler technology have evolved slowly. Early boilers resembled large teakettles. Need for reduced boiler size, increased efficiency, and improved safety, along with related developments in technology, have resulted in significant changes in design. These developments include:

(a) Introduction of welded construction;
(b) Development of safety valves and fusible plugs;
(c) Watertube designs;
(d) Enhancement of materials;
(e) Increases in design pressures and temperatures;
(f) Conversion to fuels other than coal;
(g) Use of single-wall construction;
(h) Improvements in burners and control systems; and
(i) Addition of features such as superheaters and economizers.

Reference should be made to 46 CFR Table 54.01-5(a) for applicability of regulations for various types of equipment. Boilers are divided into main and auxiliary boilers. Boilers whose primary function is to deliver steam for propulsion purposes are designated as "main" or "propulsion" boilers; all other boilers are auxiliary boilers, which may be either fired or unfired. The requirements for miniature boilers and organic fluid vaporizer generators should be noted in 46 CFR 52.25. These boilers are not widely used aboard ships, and are, therefore, not discussed further.

(5) Pressure Vessels. Pressure vessels are merely leak-proof containers for pressurized fluids. They vary in characteristics, from a simple component in a piping system to more sophisticated construction for extremes of pressure, temperature, or exacting performance requirements. [NOTE: Some fluid conditioner fittings are reviewed as pressure vessels (see 46 CFR 56.15-5]. In light of this, one should realize how difficult it is to develop general design requirements suitable for all applications. Because of the amount of energy stored in pressure vessels, preventing failure becomes a primary concern in design. Although failure may result from several causes that which first comes to mind is overstress of the material.

(6) Control of Stresses. Stresses in boilers and pressure vessels are maintained at an acceptable level by preventing overloading (as a result of overpressure, external loads, etc.); preventing reduction in load carrying cross section (as a result of corrosion, fatigue cracks, etc.); by avoiding "weak link" construction details; and by properly selecting materials. Materials, for example, must have suitable plastic as well as ductile properties so that local yielding can redistribute stresses to prevent failures that would occur in purely elastic materials. There is no perfect pressure vessel material for all applications and environments. Most pressure vessels are

3.E.2.a (6) (cont'd) designed with a "design margin" or "factor of safety" approach. However, as more is learned about design and material parameters, engineering and economic considerations will lead to increased use of refined analytical and experimental design procedures. Coast Guard engineers must keep abreast of factors affecting pressure vessel design, since they will be increasingly called upon to evaluate designs that more fully use material properties and advanced design methods.

b. Propulsion Boilers.

(1) Introduction. The importance of reliability in vessel propulsion becomes obvious as one considers the consequences of losing the main propulsion plant. The design effort devoted to reliability has been receiving increased emphasis in recent years due to growing complexity of equipment and the trend toward reduced manning. The cost of taking ships out of service for repairs has also increased the attention given to designing for reliability and maintainability. Although many operators consider two boilers necessary to ensure propulsion for the vessel in case one boiler is lost, the Coast Guard does not prohibit single boiler installations.

(2) General Requirements. Certain characteristics are important in marine boilers. It is desirable to keep the size of these components to a minimum to maximize availability of vessel cargo space. The center of gravity should be low to increase vessel stability. Boiler drums should be arranged fore-and-aft to minimize sloshing and water level control problems. Foundations must be designed to withstand loads from ship motions. Access must be carefully provided for inspections and repairs. Combustion controls must be suitable for shipboard service, which makes components such as mercury switches unacceptable. Special piping requirements help provide reliable supplies of fuel and water. Manning and automation requirements for boiler installations are geared to the increased attention required by boilers, as opposed to diesel installations. Marine boilers are designed for more potentially harmful vibration and shock loading than are shore-based boilers. These examples give some feel for special considerations relating to marine boilers and, when coupled with failure consequences typically more serious than for land-based boilers, point to the need for particular interest in reliability and safety.

(3) Main Boiler Safety Valves. The design, sizing, setting, and repair of main boiler safety valves are extremely important. The required safety valve capacities are based on the boiler overload ratings determined during design of the boilers. Re-heaters, air heaters, economizers, boiler design characteristics, and type of fuel affect these capacities. ASME does not certify or approve safety valves. When requested by ASME, the National Board of Boiler and Pressure Vessel Inspectors (NB) will survey a manufacturer's facility, valve designs, quality control systems, and flow test facility to establish valve capacity in accordance with the ASME Code. Capacity test data for each valve model, type, and size signed by the manufacturer and an authorized observer is submitted to the NB for certification. Certificates

3.E.2.b (3) (cont'd) must be renewed every 3 years. Valves certified by the NB are published in "Relieving Capacities of Safety Valves and Relief Valves Approved by the National Board," which includes relieving capacity data. Many considerations affect selection of safety valve set pressures and blowdowns. Improperly set valves can result in overpressure or overheating of the boiler, simmer, chatter, rapid cycling, frequent operation, or deterioration of the safety valves. Parts 67-73, Section I of the ASME Code contain a wealth of information on safety valves, some of which Coast Guard inspectors should know. For example, for service over 250 psig the tolerance on setting a valve is +/- 5 percent of the pressure marking on the valve. The setting of superheater safety valves may depend upon the pilot valve setting, the design pressure of the superheater, or the design pressure of the main steam piping.

Safety valves are repaired under the provisions of 46 CFR 59.01-5. Due to a previous history of unsatisfactory repairs, Repair Of Boiler Safety Valves", COMDTPUB P16700.4, NVIC 1-71, was written to set forth procedures by which the Coast Guard can accept repaired valves as equivalent in performance to that of a new valve (see below concerning the National Board).

(4) Superheaters. Of particular concern in the approval and inspection of boilers are the steam and tube metal temperatures of superheaters. Depending on the design and arrangement of superheater tubes and headers, steam temperatures in some parts of the superheater can be substantially higher than those in the superheater outlet. Tube metal temperatures also vary throughout the superheater. Highly sophisticated techniques of analysis and much experience go into predicting what these temperatures will be; these temperatures rarely turn out exactly as predicted, due to all the variables involved. For this reason, it is normal practice to outfit the first boiler in a class of vessels with thermocouple temperature monitoring systems. It is important to know what these temperatures actually are, because at high temperatures, temperature increases can result in tremendous loss of strength in the metal. Temperature increases of 250°F may result in reductions in material allowable stress of 25 percent or more, depending on the actual temperature and material. Concern for this delicate balance between temperature and allowable stress does not end with the boiler. The main steam piping from the boiler must be similarly designed for the high steam temperature. This is done by selecting appropriate allowable stress values to maintain required safety factors for pressure containment in keeping thermal expansion stresses at an acceptable level. This points to the importance of the requirement in 46 CFR 52.01-95(b)(2) for visible and audible alarms to indicate excessive superheat. All boilers with integral superheaters are approved for a maximum allowable superheater outlet temperature. For protection of both the superheater and the main steam piping, the alarm setting should not exceed this approved temperature. Recently, boiler fuel rates have become an important consideration, resulting in a trend to operate very close to the maximum allowable temperature to improve efficiency.

3.E.2.b (5) References. See 46 CFR Part 62 for information on main boiler controls, alarms and shutdowns, and how requirements for these features relate to levels of vessel manning. Additionally, see below for information on propulsion system automation.

c. Auxiliary Boilers.

(1) General. Auxiliary boilers include those shipboard units that are not used for propulsion. The high pressures and temperatures desirable for use with steam turbines make watertube boilers favored for main boilers. Auxiliary boilers, however, are supplied in quite a variety of forms, including both water and firetube types, for quite a variety of applications. These units are categorized in 46 CFR Table 54.01-5(a) as fired steam boilers, hot water heating boilers, hot water supply boilers, an unfired steam or hot water boilers (see table for applicable regulations). Except for some unfired boilers and some small electric water heaters, these units are designed, fabricated, and tested in accordance with Section I or IV of the ASME Boiler and Pressure Vessel Code, as modified by 46 CFR Parts 52-53 for Coast Guard purposes. Boilers that are not exempt from the requirements of 46 CFR Parts 52-53 must be equipped with appropriate safety valves. These valves will have quality construction, certified capacities, provision for sealing after setting the pressure, and other features required by the Coast Guard. The valves are not usually pilot-actuated on auxiliary boilers. Features and operating characteristics of boiler safety valves differ significantly from those of ordinary pressure relief valves.

(2) Fusible Plugs. Fusible plugs are also required on all boilers except watertube boilers and heating boilers operating at 30 psig or less (see 46 CFR 52.01-50). Although these plugs may relieve some pressure and provide some cooling of furnace temperature, their main purpose is to provide warning for the operator in case of extremely abnormal operation. The plugs are particularly important for a hand-fired or solid fuel boiler. Plugs are cleaned and inspected regularly to prevent unintentional failures. Low water is the usual cause of fusible plug failures, but excessive scale on the plug or adjacent metal can also melt the plug. How useful a fusible plug is in limiting furnace temperatures depends on the individual design of the boiler and controls, the plug locations, and the amount of forced draft.

(3) Relative Effects of Fuel Consumption. Fired auxiliary boilers include boilers fired by either oil or electricity. Generally, the specific requirements of 46 CFR 52 or 53 apply to these boilers, with appropriate requirements for automatically controlled boilers taken from 46 CFR 63.05 or 63.10. Control system requirements vary depending on the heat input rating, with more detailed provisions occurring for units with a heat input rate over 117 kW.

(4) Automatic Control Systems. Automatic control systems for auxiliary boilers will be reviewed by the MSC. Although approvals are issued on an individual vessel basis, standard design files

3.E.2.c (4) (cont'd) should be maintained to reduce redundant reviews. It should be noted that although nearly all auxiliary boilers are automatically controlled, the Coast Guard does not require them to be automatic. Boilers that do not meet all the requirements in 46 CFR Part 63 should be required to have a qualified operator, responsible for the operation of that boiler, present whenever the boiler is in operation.

[NOTE: This may impact on the manning requirements for the vessel aboard which the boiler is installed.]

(5) UL listings. Certain electrically fired hot water supply boilers (water heaters) may be accepted on the basis of listing by UL (see 46 CFR 53.01-10(c)). The scope of UL 174 has been substantially reduced since this regulation was written, so that it now applies only to household-type water heaters. UL has developed a new standard for commercial type heaters, UL 1453, that has been evaluated and adopted by the Coast Guard. [NOTE: the requirements found in 46 CFR 63.25-3 for water heaters not covered by UL 174 are intended to prevent water in any part of the storage tank from flashing to steam at atmospheric pressure. Some lack of clarity presently exists between the 46 CFR Part 53 and Part 63 requirements for relief of pressure for water heaters up 100 psig. What should be provided is either an approved safety valve and a temperature relief device or a pressure-temperature relief valve meeting ANSI Z21.22.]

d. Unfired Boilers. Because of an increased interest in energy conservation, increased numbers of waste heat boilers are being built for marine applications. Most of these units are exhaust gas types designed to recover usable heat that would otherwise be lost. The controls for these boilers are usually very simple; the generated steam can be used directly for heating or doing work, or routed to the drum of a fired auxiliary boiler aboard the vessel to supplement its capacity. When two boilers are connected in this manner, the system must be reviewed to ensure that adequate total safety valve capacity is provided and to verify that one boiler cannot be a source of overpressure for the other. The controls on the fired boiler must be sufficiently flexible for operation with or without input from the unfired unit. If the waste heat boiler is capable of being run dry, as most can (either intentionally or unintentionally), the boiler must be designed for the highest possible exhaust gas temperature, not the saturated steam temperature. Also, since most waste heat boilers are relatively low-pressure, low-temperature units, the consequences of failure are sometimes underestimated. Often, they are installed directly over the main source of power for propelling the vessel. In these cases, unless suitable warnings, alarms, or baffles are provided, a significant boiler leak (or a small leak over an extended time when the vessel is not underway) could result in loss of propulsion before anyone is aware of the leak. Such precautions are normally required where the exhaust gas temperature can exceed 800°F and plain carbon steel tubes are used. This is because the steel may deteriorate at higher temperatures due to the carbide phase of the steel being converted to graphite. This same problem may occur in carbon-molybdenum steel above 875°F.

e. ASME Code, Sections I And IV.

3.E.2.e (1) Introduction. The Coast Guard has, in 46 CFR 52-53, adopted Sections I and IV as the governing standards for design, construction, and testing of power, auxiliary, and heating boilers subject to Coast Guard inspection. These standards also apply to repairs made to new boilers. Prior to 1968, most of the requirements for boilers were actually contained within 46 CFR 52-53. However, welding requirements were in Part 56, testing in Part 61, and materials in Part 51. This made it extremely difficult to follow the requirements for new construction. The regulations now basically adopt the ASME Code, but do change or modify the code sections in some areas. For example, some piping areas covered in Section I have been replaced with the requirements of 46 CFR 56, to maintain consistency with other piping requirements of the Coast Guard.

(2) Applicability. The ASME Boiler and Pressure Vessel Code is recognized and accepted throughout the world. Worldwide use of this standard has become even more prevalent with the issuance of ASME Code symbol stamps to foreign manufacturers. [NOTE: The code is applicable to new construction only.] The rules are intended to provide minimum requirements for safety and serviceability. A designer must realize this and design for an intended service, while at the same time satisfying the minimum rules of the code. A boiler or pressure vessel designer can fully comply with code requirements, for example, without selecting materials appropriate for the intended service. A boiler must be designed for loads due to ship's motions, thermal conditions, etc., although the code provides no formulas for such loads.

(3) Historical Basis. The basic principles of design are shared between Sections I, IV and VIII of the code and will be discussed more fully later in this manual. The differences in applicability and details, however, are significant and must be fully understood by users. Section I, Power Boilers, was developed because of a rash of boiler explosions that occurred in the late 1800's and early 1900's. A catastrophic boiler explosion in a Brockton, Massachusetts, shoe factory that killed 58 persons, injured 117 others, and caused tremendous property damage resulted in the Commonwealth of Massachusetts enacting construction rules for boilers in 1907; the State of Ohio issued similar rules in 1908. ASME first published Section I, Power Boilers, in 1914. Due mostly to the development and adoption of these rules, failures of boiler pressure boundaries are practically nonexistent today. Section IV, Low Pressure Heating Boilers, was published in 1923. Section II, Materials, was published in 1925. Section VIII, Pressure Vessels, was published in 1925. Section IX, Welding Qualifications, was published in 1937. Section VIII, Division 2, Pressure Vessels, was published in 1968. The Coast Guard routinely works with these code sections, which are continually revised and updated. Coast Guard participation on code committees is an important aspect of the regulatory process.

(4) Summary. The prefaces of Sections I and IV contain important information regarding the scope of applicability of the sections.

3.E.2.e (4) (cont'd) It is important to know how the Coast Guard may adopt or modify these provisions. When are superheaters, economizers, or unfired steam generators designed in accordance with Section I, and when must they meet the requirements of Section VIII? Must a 25 psig heating boiler meet Section I or Section IV? Which steam piping must meet Section I, and which piping must meet 46 CFR 56? The answers to questions such as these must be clearly understood by Coast Guard marine safety personnel.

f. Thermal Fluid Heaters (TFHs).

(1) Introduction. TFHs are being used increasingly in marine applications, both in this country and overseas. Although these heaters may be either fired or unfired, fired heaters are by far the most common. There are many possible applications for thermal fluid heaters for heating, heat recovery, or cooling. These units may be used to maintain the temperature of heavy fuel, preheat lube oil or cooling water, space heating, unfired steam generation, tank washing heat exchangers, cargo pipe tracing, and other applications. The most common application with which Coast Guard personnel are involved is the heating of petroleum products or other chemicals carried as cargo on ships or barges. Many of these cargoes must be heated to maintain pumpability. Fires in connection with TFHs are a very real potential hazard. Most heat transfer fluids are combustible and are, of course, heated during TFH operation. Fuel is being pumped to the burners. Flames, hot surfaces, and electrical sources of ignition may all be present. Therefore, one should not underestimate the potential hazard of these units just because associated pressures may be low and steam is not being generated. It is recommended that special attention be given during inspections to operational testing and visual checks of piping, pipe connections, and mountings. Operating manuals approved for fired TFHs should include a detailed test procedure for controls, alarms, and shutdowns.

(2) Adherence to 46 CFR Parts 52 and 63. Table 54.01-5(a) shows that the requirements of 46 CFR 52 and 63 are applicable. Essentially, this is saying the heater will be constructed per ASME Code, Section I, and have controls, alarms, and shutdowns similar to those required for auxiliary boilers. In fired TFHs, forced circulation with a continuous positive control of fluid in each heating coil or tube is very important. In a "firetube" type of heater, it would not be possible to adequately control fluid velocity throughout the heater. The usual watertube boiler type design also inadequately controls heat flux rates throughout a fired TFH. The most popular shipboard design today employs a limited number of watertube coils to control circulation (sometimes only one coil is used). The smaller units may use only radiant heating, with larger units also having a convective section. Fluid velocities that are too low will result in high film temperatures and decomposition of the fluid. No phase change in the fluid should occur in a TFH, or upon leakage from the system. The coil design usually will not accommodate the installation of soot blowers, making manual cleaning necessary while the heaters are shut down. Expansion tanks should be mounted high enough in the system to provide a positive head to

3.E.2.f (2) (cont'd) prevent the ingress of cargo or other heated liquid if a tank coil or heat exchanger should fail. These tanks are left uninsulated to avoid heat buildup and fluid oxidation.

(3) Requirements for Fired TFHs. Fired TFHs must not be installed in hazardous locations. Heater fuel systems must comply with 46 CFR 56 requirements for fuel piping. Hot surfaces must be insulated as required by 46 CFR 56.50-1(k) to prevent injury to personnel. Relief valves must be installed to protect the heater in event of clogging or inadvertent valve closure. These valves normally relieve to the expansion tank. In the past, the Coast Guard has considered the flash point of the heat transfer fluid to be the practical safe limit of operating temperature for TFHs, and the high temperature cut-off settings are approved accordingly. A leak into a space is considered less hazardous in the form of a combustible liquid than as a potentially explosive cloud of vapor.

Simple heaters with non-corrosive fluids generally warrant less attention during operation and less maintenance on the heater proper than do steam units. However, the controls, alarms, and shutdowns should be regularly tested and maintained. Controls, alarms, and shutdowns for fired TFHs are similar to those required for boilers. Burner control can be on/off, high/low/off, or fully modulating, depending on type of fuel and heater size. Burner sequences are controlled by a timer, which is programmed to check the operation of controls and safety devices while monitoring the flame by photo-electric or ultraviolet sensing. Fluid temperatures are usually controlled by thermostats, with sensing elements typically installed at the inlet header and the outlet of each coil. Fluid flow, fluid level, and temperature measuring devices automatically shut down the burner under abnormal conditions. Requirements for controls and shutdowns are detailed in 46 CFR 63.

(4) Use of Heat Transfer Fluids. Most of the heat transfer fluids used today are mineral oils or synthetic hydrocarbons. Isomers and diphenyl-diphenyl oxide are also occasionally used. Other types of fluids are available for special applications. What makes these fluids better than steam for heating purposes? First, the economy and safety of a low pressure system can be realized, since the temperature is not pressure-dependent as in the case of steam. Lower pressure also decreases leakage potential and the possibility of contaminating the product being heated. Many chemicals that would react strongly with water are more compatible with heat transfer fluids. Thermal fluids may be pumped at low temperatures, and have no condensate return lines to freeze. Feed water treatment is eliminated. Internal scaling and corrosion are greatly reduced. These fluids do not form a vacuum in the system after shutdown, which would tend to contaminate the fluid. Despite these features, there are some problems with heat transfer fluids that should be understood:

(a) The fluids are combustible, requiring equipment and procedures to minimize fire risk. They also constitute a potential water pollutant.

3.E.2.f(4)

(b) The fluids may oxidize when exposed to air. Sensitive temperature control is required to prevent boiling, coking, scaling, or fluid deterioration due to high fluid film temperatures in the heater.

(c) Deterioration in service can result in lowering of the flash point and increase in carbon residue.

(d) The fluid should be handled cautiously since exposure to skin, eyes, lungs, or the digestive system can be irritating or cause illness.

(e) Heat transfer fluids have a lower coefficient of heat transfer on the inside tube surface than does steam, necessitating higher operating temperatures or more surface area for the same performance. Fluid circulating pumps can be high maintenance items.

(f) Also, although there are some offsetting factors in the cost of these fluids, they are expensive.

Work is being done to develop water-based heat transfer fluids to reduce costs. Water has some advantages over oil in that it has excellent heat transfer properties, low viscosity, low vapor pressure, high thermal conductivity, and high specific heat and density. It is not combustible or toxic. Additives are being developed to reduce its limitations regarding operating temperature, corrosion, freezing, etc. This use of water is promising but has had little success so far. [NOTE: The preceding discussion is intended as an introduction to TFHs used in marine applications. Large heaters found in the chemical processing industry are normally much more sophisticated in design.]

g. Pressure Vessels.

(1) General Requirements.

(a) Historical Basis. In the early 20th Century, materials and technology were such that pressure vessels were limited to a capacity of a few hundred pounds per square inch (psi) pressure. Even at that, explosions of such equipment were not uncommon. A real need was realized for the development of materials, design and fabrication methods, protective devices, and quality control procedures. Cities, states, and other jurisdictions began development of design, construction, and inspection rules to help prevent pressure vessel failures. As these rules were enforced, it became more and more difficult to construct a pressure vessel in one jurisdiction that would be accepted in another, due to conflicts in the applicable rules. Because of this lack of uniformity, the ASME Pressure Vessel Code was developed in 1925. This was an attempt to offer the various jurisdictions a standard set of design and construction rules for safe pressure vessels. Much progress has occurred since that time. Pressure vessels are now being built for service at pressures of several thousand psig and equally severe

3.E.2.g(1) (a) (cont'd) temperatures. The Code is continuously updated by the ASME Boiler and Pressure Vessel Committee to keep up with growth in the pressure vessel industry.

(b) Coast Guard Adoption of the ASME Code. On 1 July 1969, the Coast Guard adopted the ASME Code for pressure vessels under its jurisdiction. Section VIII, Division 1 is adopted for most, but not all, pressure vessels aboard Coast Guard certificated vessels. 46 CFR 54 adopts the code, while modifying some of its provisions to conform more appropriately to marine practice. Therefore, a comprehensive understanding of pressure vessel requirements can only be achieved by reading the ASME Code, along with the modifications from Part 54. The code applies to many types of welded and forged pressure vessels. However, there are many pressure vessels outside the scope of the code, as adopted, that must be reviewed on an individual basis. These include non-metallic vessels, wire-wound vessels, multi-layer vessels with shrink-fitted shells, vessels with design pressures in excess of 3000 psig, etc. These types of pressure vessels are normally submitted to Commandant (G-MSE-3) for review. There have been few marine applications of these vessels to date; however, the use of very high-pressure accumulators for hydropneumatic service is becoming more common.

(c) Exemptions From Compliance. 46 CFR Part 54 exempts certain categories of pressure vessels from plan review and shop inspection for various reasons. Some exemptions are conditional on the presence of the "U" or "UN" code symbol. The "U" stamp signifies that the pressure vessel complies with the applicable design, fabrication, and testing requirements of the code, and has been inspected by an authorized inspector. The "UN" stamp indicates code compliance, except that the independent third party inspection is not required (see paragraph U-1 of Section VIII, Division 1 for applicability of the "UM" stamp). The presence of a code stamp is not required to be on pressure vessels that must receive Coast Guard plan approval and shop inspection. The Coast Guard issued Final Rules, effective 21 June 1982, that require Class I, II, and III pressure vessels not containing hazardous materials to be inspected and stamped in accordance with the ASME Code. These rules replace previous requirements for plan approval and shop inspection by the Coast Guard. These rules require:

i. Certification of pressure vessel design drawings and analyses by a registered professional engineer (under 54.01-5(e));

ii. Coast Guard inspection of the completed pressure vessels prior to installation, 54.10-3(c); and

iii. Compliance with certain requirements which are optional under the ASME Code (see 54.01-5(d)).

3.E.2.g(1)

(d) Revisions of the ASME Code. The Boiler and Pressure Vessel Committee meets regularly to consider proposed additions and revisions to the code and to formulate code cases. Proposed changes are published in ASME's magazine Mechanical Engineering for public comment from all interested persons. After the allotted time for public review and final acceptance by the ASME Council, the Addenda (which include the additions and revisions to individual sections of the code) are published twice a year. These addenda are accepted by the Coast Guard for new construction 6 months after their date of issue. Code cases do not revise the code. They are issued to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or construction not covered by existing Code rules. Code cases are published in two separate books, Boilers and Pressure Vessels and Nuclear Components. Code cases are not adopted by the Coast Guard unless specifically authorized by the Commandant.

(e) Coast Guard Modifications of the ASME Code.

i. One of the Coast Guard modifications to the code is the division of pressure vessels into various classes such as Class I, Class II-L, etc. These categories are used in defining exemptions from Coast Guard requirements, or in specifying additional requirements, such as for welded joints, nondestructive testing, or heat treatment (see 46 CFR Table 54.01-5(b)). These additional requirements provide for specific marine service and, in general, represent owner-option alternatives under the code. The jurisdiction of the code with regard to external piping ends at the first circumferential joint in welded end connections, the face of the first flange in bolted-flange connections, and the first threaded joint in threaded pipe connections.

ii. The requirements that 46 CFR 54 contain "modifications" to the adopted code are significant and straightforward, and should be reviewed by marine safety personnel approving or inspecting pressure vessels. They discuss loadings due to ship's motions, corrosion allowance and protection, external pressure, low temperature service, toughness testing of materials, inspections, stamping, data reports, pressure relief devices, pressure relief under fire conditions, welding, nondestructive examination, materials, and stress relief.

(2) Stress Calculation.

(a) Introduction.

i. To determine the allowable design stresses for multi-axial stress conditions that occur in pressure vessels, several theories of failure have been developed. Since all sections of the ASME Code do not base design requirements on the same failure theories, it is worthwhile to briefly consider these concepts. The

3.E.2.g(2)(a)

i. (cont'd) purpose of the failure theories is to predict when failure will occur due to combined stresses on the basis of data gained from simple uniaxial tests.

ii. Section I and Section VIII, Division 1 are based on the "Maximum Stress" or "Rankine" Theory. Under this theory, failure occurs when one of the principal stresses reaches the yield point value in tension or compression. The principal stresses in a cylinder are axial stress, radial stress, and tangential or hoop stress. Section III (Nuclear Power) and Section VIII, Division 2 are based on the "Maximum Shear Stress" or "Tresca" Theory. Under this theory, failure occurs when the maximum shear stress reaches some critical value, which depends on what type of loading the pressure vessel part is experiencing. The equation for stress analysis known as the Lame Equation, which is frequently used in analysis of thick wall cylinders, is based on the maximum stress theory. The ASME modified membrane equation,

$$t = \frac{PR}{SE - 0.6P} + C$$

is in very close agreement with the Lame Equation, and also takes into account weld joint efficiency and corrosion allowance (see ASME Section VIII, Division 1, UG-27 for definition of symbols). In a thin cylinder under internal pressure, where the radial stress is close to zero, the maximum stress and maximum shear stress theories give approximately the same results. However, in thick-wall cylinders having a radial stress that is not small in comparison to axial and hoop stress, the maximum shear stress theory will give results that coincide more closely with experimental data. It should not be concluded, however, that a thin-wall pressure vessel designed under Section VIII, Division 1 will be the same as one designed per Section VIII, Division 2. Safety factors and other parameters in the code sections differ significantly, as will be discussed in more detail later. One important characteristic of the maximum shear stress theory is that it can predict the failure of a material under either static or fatigue loading with good accuracy. It also gives excellent agreement with experimental results in the case of high tensile steels.

(b) Alternate Stress Theories. Two other failure theories should be mentioned, although they are not widely used in pressure vessel design. In the "Maximum Strain Energy" Theory (also known as the "distortion energy" or "Von Mises" Theory), rupture occurs when the strain energy per unit volume reaches a critical value. In the "maximum strain" theory, the part will fail when the maximum strain equals the strain at the elastic limit under simple tension.

3.E.2.g(2)

(c) Application of Engineering Judgment. One cannot be satisfied with a determination of stresses from a design analysis until all loads have been adequately considered. Paragraph UG-22 of Section VIII, Division 1 lists several types of loading that may be imposed on a pressure vessel, and that should be taken into account by the designer. 46 CFR 54.01-30 adds to this list by including static and dynamic factors peculiar to marine applications. During plan approval, some engineering judgment must be applied in deciding which of these loads will have a potentially significant effect on vessel stresses. For example, large low pressure tanks containing liquids may be highly stressed by both static liquid head and saddle supports. Liquid contents raise the reaction forces of the saddles. Sloshing loads could also be high in large liquid-containing vessels when baffles are not provided. Changing orientation of a ship (list and trim) or dynamic characteristics of a particular ship may sometimes need to be determined and used in defining pressure vessel loads. In most cases when a ship's motions should be considered, a simplified method that has proven satisfactory in the past has been to apply a static weight factor of 2G downward, and a 1G force in the fore-and-aft and athwartships directions. For the vast majority of pressure vessels approved under Part 54, dynamic loading from ship's motions need not be checked. Good engineering judgment must be applied in every case.

(d) Design of Saddle Supports for Horizontal Pressure Vessels. This is usually done with the assistance of a paper written by L. P. Zick, although other methods (including finite element analysis) may be used. Zick's paper, "Stresses in Large Horizontal Cylindrical Pressure Vessels on Two Saddle Supports," was published in the Welding Journal, Res. Suppl. 30 (1951). Although Zick's paper may be modified to accommodate vessels on three saddle supports, use of more than two saddles should usually be discouraged on a flexible foundation such as a ship. If all supports are not perfectly aligned, additional loads will be imposed on the vessel. Although Paragraph UG-22 requires that loadings must be considered, it does not give clear information on how to do so.

(e) Additional References. Some other references that may be useful in approving pressure vessel plans are:

i. Process Equipment Design, by Brownell and Young; John Wiley and Sons, Inc.

ii. Pressure Vessels - The ASME Code Simplified, by Chuse; McGraw-Hill Book Company, Inc.

iii. Theory and Design of Modern Pressure Vessels, by Harvey Van Nostrand; Reinhold Publishing Company.

iv. Defects and Failures in Pressure Vessels and Piping, by Thielsch, Reinhold Publishing Company.

3.E.2.g(2)(e) v. Formulas for Stress and Strain, by Roark; McGraw-Hill Book Company, Inc.

(3) ASME Code, Section VIII, Division 1.

(a) Introduction. Since Section VIII, Division 1 of the ASME Code is so frequently used, this section is provided to detail these rules and their correct application. Most comments are intended to clarify or explain the basis of code requirements. Much of what is said will apply to Section I of the Code as well. The basic design criteria of Section VIII, Division 1 of the ASME Code is to provide adequate wall thickness in a vessel so that the maximum membrane stress does not exceed the allowable stress. The maximum allowable tensile stress values permitted for the various materials are given in Subsection C, Table UCS-23 of the code. The basis for establishing the allowable stress values is given in Appendix P. At temperatures below the creep range, except for bolting materials, the allowable stresses are generally based on the lowest value of the following:

i. 1/4 of the specified minimum tensile strength at room temperature;

ii. 1/4 of the tensile strength at temperature;

iii. 5/8 of the specified minimum yield strength at room temperature for ferrous materials;

iv. 5/8 of the yield strength at temperature for ferrous materials;

v. 2/3 of the specified minimum yield strength at room temperature for nonferrous materials; or

vi. 2/3 of the yield strength at temperature for nonferrous materials.

The code provides for increasing these allowable stresses for certain austenitic and nonferrous material. These higher allowable values are not recommended for flanges and other strain sensitive uses.

(b) Temperatures Below The Creep Limit. If bolting materials are used at temperatures below the creep range, with material strength increased by heat treatment or strain hardening, the following additional limits apply:

i. 1/5 of the specified minimum tensile strength at room temperature;

ii. 1/4 of the specified minimum yield strength at room temperature;

iii. At temperatures above the creep range, the allowable tensile stresses are based on the lowest value of the following:

3.E.2.g(3)(b)iii

a. 100 percent of the average stress for a creep rate of 0.01 percent in 1000 hours;
b. 80 percent of the minimum stress for rupture at the end of 100,000 hours; and
c. 67 percent of the average stress for rupture at the end of 100,000 hours.

The allowable compressive stress is the same as the allowable tensile stress value, or the value determined according to UG-23(b), whichever is lower.

(c) Localized and Secondary Bending Stresses. It is recognized that high localized and secondary bending stresses exist in code vessels. Design rules for construction details have been written to hold such stresses at a safe level consistent with experience. One reason for the 3,000 psig limit on the scope of Section VIII, Division 1, is that many of these construction details are not appropriate for higher pressure applications. The basic design of specific parts such as heads and shells are covered by code design rules. However, if a vessel is subjected to severe cyclic operation, is in some other severe service, or has a complex geometry not covered by the rules, additional stress analysis will probably be necessary. Since Division 1 is primarily for membrane vessels, stress in the radial direction is usually not considered.

(d) Hoop Stresses. The general design formulas are given in UG-27. The hoop stress formulas are limited to a wall thickness not exceeding one-half of the inside radius and pressure not exceeding 0.385 SE (symbols defined in the code). When these limits are exceeded, the UA-2 (A)(1)requirements must be followed. The longitudinal stress formulas are limited to a maximum thickness of one-half of the inside radius and a thickness not exceeding 1.25 SE, with UA-2 (A)(2) followed beyond these limits. In a thin-walled cylinder with hemispherical heads, the average hoop stress in the shell is about twice the average axial (longitudinal) stress in the shell and twice the average stress in any direction of the hemispherical head. The average radial stress on the cylinder and head is compressive and equals one-half the internal pressure. This shows that, for internal pressure, the average hoop stress usually controls. Design formulas for other than hemispherical heads are based on a combination of analytical stress analysis, experimental stress analysis, and experience. The flat head formula must be adjusted for various details of joint design.

(e) Failure Criteria. The failure criteria used for external pressure or axial compression is elastic instability (buckling) and yielding from compressive stress. Provisions are included for design of stiffening rings. The minimum required thickness is found by a trial-and-error method. Once again, some materials have lower temperature limits in the stress curves for external pressure than the same materials in the tensile stress tables.

3.E.2.g(3)

(f) Shell and Head Openings. Openings in shells and heads must be designed per UG-36 through UG-42. When this is not practical, the ligament efficiency rules of UG-53 may be used. In viewing a cross section of the opening, adequate excess material must exist in the vessel and nozzle wall, or be added around the opening, to replace the material missing in the corroded hole in the vessel wall. Appendix L gives examples of application of these rules that are very helpful. In addition to providing the area of reinforcement, adequate welds must be provided to attach the reinforcement metal, and the induced stresses must be evaluated. The goal is to compensate for the weakening effect of the opening with metal of a suitable profile so as not to introduce an overriding stress concentration itself.

(g) Welded Joints. In applying code requirements for welded joints, it must be remembered that they are minimum requirements; design loads may require construction that is more restrictive. Requirements for weld geometrics, sizes, and details are contained in Part 13W. Section VIII, Division 1, as it is presently written, generally bases allowable stresses on one-fourth of ultimate tensile strength, as discussed earlier. However, to allow this stress value and the associated wall thickness and safety factors, the code requires mandatory examination of all butt welds by radiography. When butt welds are not radiographed or where butt welds are not used, the wall thickness and safety factor required are increased by Factor E in the design formulas. Factor E is referred to as the "joint efficiency" of the weld. In fact, this terminology is not all that appropriate. It is a carryover from before 1930, when most pressure vessels were of riveted construction. "Joint quality factor" is a more appropriate term, but "joint efficiency" will be used for consistency with the code. The intent of the code is to have three quality levels, one where all butt welds in the vessel are fully or partially radiographed, one for spot radiography, and one for welds without radiographic examination.

(h) Code Distinctions Covering Welded Joints. It is important, when doing pressure vessel plan review for the Coast Guard, that one understand the purposes and differences between the following paragraphs:

i. UW-2 Service Restrictions;
ii. UW-3 Welded Joint Categories;
iii. UW-11 Radiographic Examination;
iv. UW-12 Joint Efficiencies; and
v. Table UW-12, Maximum Allowable Joint Efficiencies.

A reviewer must have a complete understanding of service restrictions, joint design, and joint examination requirements to be able to correctly apply the code. This understanding is best gained by careful study of the content and intent of the code rules. If the design formula used has an E value selected from Table UW-12, the quality factor is

3.E.2.g(3) (h) (cont'd) built in and no further consideration is required. However, formulas that do not contain an E value, which are used to calculate parts of vessels that include non-examined butt welds, require addition of an 80 percent quality factor or an 85 percent factor where spot radiography is used. Joint "category" designations are locations of joints in a vessel, and have no bearing on the type of joint. The February 1975 issue of ASME's Journal of Pressure Vessel Technology contains an article by G. M. Eisenberg that is of great assistance to understanding E factors and stress multipliers, and how they relate to requirements for radiography of butt welds; examples shown in Appendix "L" of the code will also be helpful. Since the degree of radiography affects the safety factor of a vessel designed to code rules, it helps to be reminded that no amount of radiography increases the strength of a weld. Only the assurance of weld quality is increased. [NOTE: Supplementary design rules are contained in Mandatory and Non-Mandatory Appendices of the code. Space does not permit discussion of all these provisions. However, those pages contain a wealth of requirements, recommendations, and information of which a code user should be aware.]

(4) ASME Code, Section VIII, Division 2.

(a) Introduction. Section VIII, Division 2 of the code contains alternative rules for pressure vessel design. Under Division 2, it is possible to design pressure vessels with a theoretical design margin (factor of safety) of three, based on the ultimate tensile strength of the material. This differs from Division 1, which essentially requires a design margin of five (which can be reduced to as low as 3.5 if certain procedures such as radiography are used).

These rules may not be used for portable pressure vessels other than pressure vessels for human occupancy (PVHO's) used in diving operations. Because of the demand for higher pressures and temperatures for pressure vessels and limitations on availability of materials, Division 2 was developed and published in 1968. Its main goal was to provide for better utilization of existing materials. What does this lower factor of safety really mean? Essentially, with the higher stresses allowed, it offers the possibility of manufacturing a lighter vessel, with thinner shells and heads and less weld metal; but the lighter vessel may carry a higher price tag. There are many restrictions on material selection; a very detailed stress analysis is required. Inspection and testing procedures are much more comprehensive than for Section VIII, Division 1 vessels. In fact, the costs of the extra engineering and inspection efforts will often outweigh the savings in material and fabrication costs.

(b) Professional Certification. One important feature of Division 2 is that the user of the vessel is required to present the manufacturer detailed information about intended operating conditions. This information must be certified by a registered professional engineer experienced in pressure

3.E.2.g(4) (b) (cont'd) vessel design. The manufacturer's design report and the design calculations must also be certified by a registered professional engineer. This is to ensure that all loadings and service conditions, such as cyclic service, corrosive environments, low temperature applications, etc. have been properly taken into account. [NOTE: The quality control procedures required for Section VIII, Division 2 vessels is comparable to those required in Section III for nuclear vessels.]

(c) Stress Evaluation and Design Review. Stresses in Division 2 are divided into various categories, and allowable stress values vary according to the type of stress being evaluated. Much of the stress terminology used in Division 2 is foreign to Division 1. For example, allowable stress values are expressed in terms of "stress intensities." As noted above, Division 2 is based on the Maximum Shear Stress Theory of failure. Under this theory, the yield stress of a material is equal to the difference of the maximum and minimum principal stresses, or twice the maximum shear stress. In Division 2, the specified yield stress is called the "stress intensity" of the material. How does Section VIII, Division 2 permit higher allowable stresses without reduction in safety? This is accomplished by requiring a rigorous analysis, and classification of all types of stresses and loading conditions. This is called "design by analysis." Manufacturing and inspection procedures are also better controlled. Certified design specifications and a formal stress analysis document, both signed by a professional engineer involved in pressure vessel design, are required. Section VIII, Division 2 vessels are normally reviewed by Commandant (G-MSE-3).

h. Heat Exchangers.

(1) Introduction. Heat exchangers are widely used aboard ship to transfer heat from one gas or liquid to another. Shell-and-tube exchangers are the most common marine type, except that deaerating feedwater heaters are often a direct-contact type. The more simple variety has straight tubes, fixed tubesheets, and are single-pass (i.e., the tube side fluid flows in one direction only); a two-pass unit has the inlet and outlet connections at the same end.

Some units, such as oil coolers, may have a floating tubesheet at one end to accommodate differential thermal expansion between the shell and tubes. Shell expansion joints and U-tube designs are also used. In coolers using seawater as the cooling medium, galvanic protectors (usually zinc) are used to protect the parts from galvanic corrosion. The joint most likely to leak in a heat exchanger is the tube-to-tubesheet joint. The tubes are normally expanded into the tubesheet using a mandrel, and care must be taken to use a correct procedure to ensure a tight joint. Tubes sometimes are fitted with fins to increase the heat transfer area of the exchanger. Sometimes baffles are installed in the shell to direct the shell-side flow and to provide tube supports. Marine heat exchangers are usually designed to perform in

3.E.2.h (1) (cont'd) conditions up to a 30 degree roll. Copper-nickel alloys, bronze, and various product forms of steel are the common materials used in marine heat exchangers. Marine heat exchangers are designed and located to facilitate cleaning and inspection in what is often a tight space. Inspection requirements must be taken into account in designing and locating the equipment.

(2) General Requirements. The designer of a marine heat exchanger must be attentive to the reliability of the heat exchanger in doing its job, while at the same time meeting requirements of TEMA, ASME, a classification society, the owner, and the Coast Guard. The Coast Guard, being primarily interested in the safety of the heat exchanger as a pressure vessel, places more emphasis on the design of the pressure envelope than on performance requirements. The criteria for acceptance as a heat exchanger is basically that of acceptable performance after installation. As a pressure vessel, however, the unit must meet the appropriate requirements of 46 CFR 54, unless exempted by 54.01-15(a)(4) or (5). Exemptions based on volume should be determined through the net internal volume of the shell (excluding tube volume). Some heat exchangers may at times operate with a vacuum, and consequently must be designed for external pressure. Any part of the exchanger must be designed for the greatest pressure differential that may occur across that part, including failure of an adjacent pressure boundary. Thus, shells must survive tube failures. Tubesheets or partitions with positive pressure on one side and vacuum on the other must be designed for the maximum total pressure differential to which the part may be subjected.

(3) Fuel Oil Heaters. Fuel oil heaters normally use steam as the heating medium. Close control of the heat is needed to provide temperatures high enough for proper fuel atomization, but low enough to keep carbon residues from forming in the heaters. Electric element immersion heaters must meet the requirements of 46 CFR 111.85. If fluid from a fired thermal fluid heater is used to heat fuel, it is recommended that the piping for the heat transfer fluid be so arranged that the heat transfer fluid pressure will be higher than the fuel pressure. This should be the case whether the system is operating or shut down.

This will reduce the risk of fuel leaking into the heat transfer fluid and being pumped through the thermal fluid heater.

This arrangement can be accomplished by maintaining a head on the fluid side with an expansion tank at a location higher than the fuel being heated; an alternative is to provide an intermediate heat exchanger. The U.S. Navy sometimes uses double-tubesheet exchangers to avoid contamination of one fluid by another. [NOTE: Unfired steam generators are boilers, rather than heat exchangers, for purposes of applying 46 CFR 54 requirements.]

(4) Pressure Relief Requirements. Pressure relief device requirements for heat exchangers are found in 46 CFR 54.15. Essentially, if the shell pressure is lower than the tube pressure, the shell side should be adequately protected in the case of a tube failure. If the only source of pressure on the high pressure side is an upstream pump, then a relief valve in

3.E.2.h (4) (cont'd) the piping between the pump and the heat exchanger may be used in lieu of a device installed directly on the high-pressure side of the heat exchanger.

i. Authorized Inspectors And Holders of ASME Code Symbol Stamps.

(1) Introduction. To assure integrity in the manufacture, installation, and testing of pressure vessels, independent third party inspection is required. Because of the special interests involved, manufacturers and users are not solely relied upon to ensure compliance with Coast Guard or ASME Code requirements. Coast Guard personnel inspect nearly all pressure vessels installed aboard certificated ships. However, some pressure vessels are exempt from Coast Guard plan review and shop inspection by 46 CFR 54 based on the presence of an ASME Code Symbol Stamp on the vessel. In these cases, the Coast Guard accepts the services of an "authorized inspector" (Al) in lieu of shop inspection by Coast Guard personnel (see paragraph UG-91 of Section VIII, Division 1 concerning Al's). In accepting pressure vessels with an official "U" or "UM" stamp, as set forth in Section VIII, Division 1, the Coast Guard is assured that certain quality control procedures are being followed by the manufacturer to provide compliance with code requirements. To receive a Certificate of Authorization to use a "U" or "UM" stamp, a manufacturer must have and demonstrate a quality control system established to meet code requirements.

(2) National Board of Boiler and Pressure Vessel Inspectors.

(a) Introduction. With headquarters in Columbus, Ohio, the National Board (NB) was formed to promote safety and uniformity in construction, installation, and inspection of boilers and pressure vessels, and to establish reciprocity between the United States and Canada. All Canadian provinces and most U.S. states require boilers and pressure vessels to be inspected during fabrication by an inspector holding a NB commission, and then to be stamped with a NB standard number. Qualified authorized manufacturers must be registered with the NB, and a data form for each vessel is maintained on file by the NB. To receive an NB commission, an inspector must meet minimum requirements of experience and education, pass a written examination, and be employed by a jurisdiction or an authorized inspection agency (such as a company that insures boilers and pressure vessels). The inspector may be employed by the manufacturer only if the products will be used exclusively by that company.

(b) Activities. Companies applying for an ASME Code Symbol Stamp are thoroughly investigated by the jurisdiction or by the NB before the company is authorized to manufacture ASME Code vessels. The Al assigned to that shop continually audits compliance of that shop with code requirements. Code requirements for manufacturers are contained in paragraph 13-2 of Section VIII, Division 1 of the ASME Code. The NB also administers the capacity certification of safety valves and safety relief valves constructed in accordance with ASME Code requirements. Since Coast Guard requirements are primarily

3.E.2.i(2) (b) (cont'd) based on ASME Code rules, valve capacities published by the NB may be used in approving valves for specific installations.

j. Foreign Manufacturers Of New Equipment.

(1) Boilers. Foreign-manufactured boilers to be installed aboard U.S. vessels must meet the requirements of 46 CFR 52 or 53.

(2) Pressure Vessels. Foreign-manufactured pressure vessels to be installed aboard U.S. vessels must meet the requirements of 46 CFR 54. If the pressure vessel requires shop inspection, this should be arranged well in advance to ensure availability of a Coast Guard inspector.

3. Piping Systems.

a. Introduction. Piping aboard inspected vessels is subject to regulation for various reasons. Failure of piping may endanger vessels, personnel, or the marine environment by:

(1) Failing to perform an essential function;
(2) Releasing energy or projecting missiles;
(3) Releasing harmful substances (hot, very cold, flammable, combustible, toxic, caustic, polluting, etc.); or
(4) Allowing the spread of fire, smoke or flooding.

Piping systems subject to requirements of 46 CFR 56 are considered to be in one or more of these categories. Unregulated systems are not regarded as being in any of these categories, and need only be safe from an occupational safety viewpoint. Such systems are required to meet commercial standards, such as being insulated, if hot, or keeping water away from electrical systems (see 46 CFR 56.04-10).

b. Piping Components.

(1) Introduction. The term "piping systems and appurtenances," as used in 46 CFR 56, includes several types of components defined in Subparts 56.10, 56.15, 56.20, 56.25, and 56.35. Questions frequently arise as to the distinctions between various types of fittings. In general, anything that is not clearly a pipe, tube, valve, flange, pressure vessel, or machine and is a pressure-containing component or appurtenance of a piping system is considered some kind of fitting. Fittings that serve no purpose other than joining pipe or tube (such as elbows and tees) are called "pipe joining fittings," unless they are covered by Subpart 56.30 or 56.35. The latter, such as "dresser" couplings, are called "special-purpose fittings"; all other fittings are called "fluid conditioner fittings." While this term refers to fittings that act on fluid (such as strainers, filters, or traps), it also applies to miscellaneous parts of the pressure boundary of a piping system (such as thermometer wells) (see 46 CFR 56.07-5(d) for more examples).

(2) General Requirements. All piping systems must have the necessary components for the safe and efficient operation of the vessel,

3.E.3.b (2) (cont'd) under 46 CFR 56.01-1(b), in combination with the "general equivalency regulations" (50.20-30, 30.15-1, 90.15-1, etc.). This appears to give the Coast Guard inspector and staff engineer nearly unlimited design authority; this is not the intent. 46 CFR Part 56 establishes requirements for typical ship piping systems.

The specific requirements of Part 56 should be used to determine what level of safety is intended. Only when systems, components, or materials not like those envisioned by the regulations are encountered should the broad authority of the general regulations be exercised. In such cases, this authority should be exercised to ensure an equal level of safety, occupational health, environmental protection, etc., and not to raise or lower the requirements. In such cases, recommendations for additional features may be made, but a clear distinction between the requirements and the recommendations must be provided. There are piping systems not subject to the requirements of 46 CFR Part 56 but still are considered of interest to the Coast Guard:

(a) Industrial systems aboard MODUs are regulated under section 58.60. The old exemption, allowing the use of any American Petroleum Institute (API) standard in any petroleum industrial piping, is no longer in effect for new vessels.

(b) Liquefied petroleum gas (LPG) cooking and heating piping and refrigeration piping are regulated by 46 CFR 58.16 and 58.20 respectively.

(c) Internal combustion engine exhaust piping is regulated by 46 CFR 58.10; Part 56 applies only to the extent called for by 46 CFR 58.10-5(d) and -10(a).

(d) Fluid power and control piping is subject to 58.30. For those systems requiring full review under 58.30, all Part 56 requirements not modified by 58.30 are applicable.

(3) Plan Review. When a system is regulated by 46 CFR 56, the requirements for plan review may be found in 56.01-10. These requirements are explained in Recommendations for the Submittal of Merchant Vessel Plans and Specifications, COMDTPUB P16700.4, NVIC 8-84. In brief, it is the intent of the Coast Guard to require only the necessary plans, material lists, calculations, analyses, etc. to verify compliance with all applicable regulations. Providing a high quality diagram and a bill of materials may relax the requirement for an arrangement plan.

(4) Classes of Piping Systems. Piping systems regulated by 46 CFR Part 56 have been divided into classes, based on the degree of hazard in the event of a failure that releases the contents. The flammability, toxicity, temperature, compressibility, and other such factors have been considered. 46 CFR Tables 56.04-1 and -2 may be used to determine the class of system in each case. This data is needed during review and inspection because many requirements, such as weld and joint details, design safety factor, etc. vary depending on class. The least hazardous systems are Class II. High-pressure or high-temperature systems

3.E.3.b (4) (cont'd) are Class I. Systems that may be below 0°F for reasons other than the surrounding weather are Class I-L or II-L instead of Class I or II.

c. Philosophy. Merchant ships do not carry large numbers of personnel as do Navy and Coast Guard ships. Therefore, the merchant ship substitute for active "damage control" is passive damage resistance. Piping is expected to resist noncombatant types of damage without intervention by the crew. Piping systems designed in accordance with 46 CFR 56 are assumed to have this resistance because they meet appropriate standards in each case for pressure-temperature safety factors, fire resistance, duplication, shock resistance, etc. The basic design standard is American National Standards Institute (ANSI) B31.1, the code used by the steam power plant industry ashore. It is comparable to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code in that it is based on a safety factor of four for primary ultimate tensile stresses, and the material properties are guaranteed by the use of acceptable specifications that call for both chemical and physical testing of each lot of material and other elements of quality control. ASME B31.1 is amended for marine use by several specific requirements of 46 CFR 56.

d. Impact of SOLAS. The International Convention for the Safety of Life at Sea (SOLAS) (discussed in volume II of the manual) has the force of law. Accordingly, some of the Marine Engineering Regulations in 46 CFR Part 56 provide for differences for vessels on international or domestic voyages. Differences are in the areas such as fire mains, bilge systems, hull penetrations, overflows, overboard discharges, and collision bulkheads.

e. Design Standards. As mentioned above, the design standards for piping systems are largely taken from ANSI B31.1, the "Power Piping" volume of the American National Standard Code for Pressure Piping. As a result of recent reorganization within ANSI and ASME, B31.1 will remain an American national standard, but will be called ASME B31.1. Any reference in this manual and in the Code of Federal Regulations to ANSI B31.1 applies equally to ASME B31.1, unless otherwise specified. This code, intended for steam power plants ashore, is modified for marine use by 46 CFR 56. General design requirements appear in subparts 56.07 and 56.60; specific design requirements are found throughout Part 56, particularly in 56.50. The basic design standard has a safety factor of four or five (between maximum primary membrane stress encountered in service and ultimate tensile strength of the material) for generally acceptable material specifications, depending on the level of design analysis, nondestructive examination, and hazard. When materials with lower levels of quality control are permitted, the safety factor should be increased proportionately. This safety factor may be as high as ten when completely untested but otherwise acceptable components are involved. It is thus difficult to separate "design" and "material" requirements in practice. Component standards like ANSI B16.5 and B16.34 provide excellent examples of the interplay between design details, pressure, temperature, material, and quality control. This is as true for systems as it is for components. The design standards are modified for marine application as follows:

3.E.3.e (1) Table 56.01-5(a) lists changes to ASME/ANSI B31.1 noted above.
(2) Section 56.01-10 shows which systems are regulated.
(3) Section 56.07-10 establishes design criteria, including the following:

(a) The maximum allowable working pressure (MAWP) must be no lower than the maximum pressure the system could be subjected to. This must be assured by the pump stall head or a relief valve, not by a regulator or control switch alone;

(b) Dynamic effects of ship motion, collision, etc., should be addressed; and

(c) Allowable stress values of acceptable materials are set, and 80 percent of these values must be used for Class I, I-L, and II-L systems not subjected to extra testing and analysis (this provides the safety factor of 5 as noted above).

(d) Section 56.60 describes acceptable materials, lists those that are generally acceptable but not listed in Sections I, III, or VIII of the ASME Boiler and Pressure Vessel Code, explains how to obtain acceptance of other materials, and states specific limitations on various materials.

[NOTE: Many of the materials listed in Tables 56.60-1(a) and -2(a) become generally acceptable as a result of changes in the allowable stresses and quality assurance provisions made by the tables and their footnotes.]

4. Specific Piping Systems.

a. Vital Systems. This term is used in several places in regulations and other documents without formal definition. A system should be regarded as "vital" if it must start or continue working to protect the vessel, personnel, or the marine environment from serious harm. This includes, but is not limited to: propulsion and its necessary auxiliaries; ship's service and emergency electrical generation and necessary auxiliaries; steering; firefighting; bilge pumping; and cargo containment systems. However, once a system or a portion of a system has been defined as vital, the specific regulatory requirements should not be applied arbitrarily. For example, aluminum and other heat-sensitive materials should not be used in vital parts of systems without specific authorization. If the vital system is one that may not continue to function after a major fire, such as propulsion or steering, the use of some aluminum components that would not be damaged by minor fires may be authorized. Dry fire mains and dry foam mains, on the other hand, must resist major fires while dry, then function properly later. Aluminum components should not be authorized in this type of system. [NOTE: In the past, the term "vital" has sometimes been used to cover "hazardous" systems as well. A hazardous system may or may not be vital. For example, a high-pressure air system used only for tools and industrial machinery could contain a great deal of stored energy and could injure personnel or even damage the ship if it failed violently. However, it is not "vital" because it could be placed out of commission at any time, even during a casualty or in a maneuvering situation, with no

3.E.4 a. (cont'd) risk to personnel, vessels, or the marine environment. Non-vital hazardous systems are subject to most regulations, but not to those specifically limited to "vital" systems.]

b. Hydraulic System.

(1) General. If a hydraulic system is of fail-safe design and is not identified in any subparagraphs of 46 CFR 58.30-1(a), it is not subject to all of the detailed requirements of subpart 58.30, but must meet the requirements of subpart 58.30-50. A hydraulic system is regarded as fail-safe under 58.30-1(a)(2) or (11) if it is equipped with features that prevent damage or injury upon failure of the power source or the system itself.

(2) Fail Safe Designs. The most common form of fail-safe feature is a spring-loaded brake that requires hydraulic pressure to release it before the system can operate. Such brakes can stop a crane load or boom in place when either the hydraulic system develops a severe leak or the power to the pump fails. This is the preferred (and typically employed) method. A second type of fail-safe feature such as slow and controlled release of the load for hatch covers is sometimes acceptable.

This variation has two potential problem areas. Normally, there will be one part, often a cylinder, that must remain intact for the fail-safe feature to remain operational. Also, slow lowering is not truly a safe failure if the system operates a crane used to hoist a diving bell or transfer personnel to and from a drill rig, so that it passes over water, over a rack of loose pipes, or through any other area where slow lowering would not actually be safe.

c. Low-Temperature Systems.

(1) Introduction. Low temperature or "cryogenic" systems are those containing a fluid, usually a liquefied gas, at a temperature below 0°F. These systems share several common hazards:

(a) Leakage of cold liquid can cause instant frostbite injuries;
(b) The cold makes many materials, including system piping and most grades of deck and hull steels, brittle and prone to sudden and severe cracking;
(c) The quantities of stored energy are enormous. Liquefied natural gas, for example, occupies only one six-hundredth of the space the same weight of gas occupies at normal pressures and temperatures;
(d) Many of the fluids are flammable, fire-reactive, or toxic, and vaporize rapidly upon release.

Therefore, in addition to the normal requirements of Part 56, specific requirements are found in 46 CFR 38, 56.50-105, 56.70, 57, 98.25, 151, and 154. These requirements deal mainly with material selection, avoidance of notches and crevices, welding qualification, containment, and vapor handling.

(2) Cryogenic Welding. In particular, the review of cryogenic welding procedures requires special consideration. The

3.E.4.c (2) (cont'd) applicable regulations and the ASME Code sections cited therein are easy to misinterpret. Normally, these procedures are submitted or forwarded to the MSC for review. The MSC will then approve the procedures subject to qualification testing to the satisfaction of the cognizant officer in charge, marine inspection (OCMI). Personnel wishing to become familiar with the review of cryogenic welding procedures should first read 46 CFR 57.03, as well as all references cited directly or indirectly by this regulation, including several parts of 46 CFR 54 and Sections VIII and IX of the ASME Boiler and Pressure Vessel Code. Sections A, IIB and IIC of the Code and the American Welding Society (AWS) Handbook should also be available for reference, particularly for the characteristics of the particular materials involved.

(3) Hypothetical Calculations. Consider the question "If two pieces of A312 Gr. 316L pipe are welded to each other for liquefied natural gas (LNG) service at -260° F, where must Charpy V-notch specimens be taken and what must the result be?" The answer is three specimens at the weld center only, tested at -270° F, 15 mils lateral expansion. A more complex version of the same type of question is "If a piece of A-312 Gr. 316L pipe is welded to a piece of A-333 Gr. 1 pipe for ammonia service at -28° F, where must Charpy V specimens be taken and what must the result be?" In this case, the answer is three specimens each at the weld center, fusion line, and 1, 3, and 5mm into the heat-affected zone on the carbon steel side only, tested at -38° F, 20 ft-lb if full-size Charpy specimens can be obtained.

d. Use of ANSI B16.5 And B16.34. Carbon and low-alloy steel, stainless steel and nickel alloy flanges, flanged fittings, flanged valves, and butt-weld end valves are covered by ANSI B16.5 and B16.34. These standards are unusual in that markings, materials, pressure ratings, and quality control are generally comparable to Coast Guard requirements. When the symbol B16, the material specification and/or grade, and the rating class can be read off the component body and/or label plate, B16.5 or 16.34 provides the acceptable pressure at the service temperature. Checks of §56.60 should be conducted to ensure there is no specific restriction on the material (like plain carbon steel limited to 775°F) and 56.07-10(c) to determine whether the full ANSI pressure rating or 80 percent of it applies. In some cases (e.g., small fittings, components with lost label plates, old stocks marked to previous editions of the standards, and blind flanges marked to the 1977 editions), the marking may be insufficient. In these cases, a mill or manufacturer's certificate, catalog data, or equal should be used to supplement the marking on the component if necessary to determine suitability for the intended service.

5. Steering Gear.

a. Introduction. The steering gear system is one of the most critical systems aboard ship. The disastrous results that can occur after the loss of steering capability in a maneuvering situation or inability to regain steering capability in a short time have been graphically demonstrated by the SEAWITCH, AMOCO CADIZ, and other casualties. Extensive activity in the development of steering gear requirements has taken place both internationally and nationally. The first set

3.E.5 a. (cont'd) of Amendments to the International Convention for the Safety of Life at Sea (SOLAS), 1974 was effective on 1 September 1984. These amendments contain the latest requirements for steering gear systems (Regulations 29 and 30). Corresponding Coast Guard regulations are found in 46 CFR 58.25 (machinery) and 33 CFR 164.39 (U.S. and foreign tanker requirements).

b. Regulatory Developments. Regulation projects have been completed to incorporate not only the steering gear sections, but also all of the SOLAS amendments into Titles 33 and 46, CFR. Most of the electrical requirements for steering gear systems have already been updated in Subchapter F. Major improvements to the steering gear systems include the steering control systems, indicating and alarm systems, and the regaining of some steering capability after a single failure. Steering gear hydraulic systems are vital fluid power and control systems. As such, the requirements of 46 CFR 56 as modified by subpart 58.30 are applicable. Portions of the systems exceeding a MAWP of 225 psig are Class I piping systems. Particular attention should also be given to mechanical connections. These are required to be only of sound and reliable construction, in many cases they represent single failure points in the steering gear system. For more on inspection of steering gear, see Volume II of this manual.

F. Vital System Automation (46 CFR 62).

1. Introduction. In 1975, the Intergovernmental Maritime Consultative Organization (IMCO) [now International Maritime Organization (IMO)] adopted Resolution A.325 (IX), "Recommendations Concerning Regulations for Machinery and Electrical Installations in Passenger and Cargo Ships." This resolution addressed, among other things, periodically unattended machinery spaces; it recommended that governments apply as soon as possible regulations set out in the resolution, in conjunction with the applicable requirements of SOLAS 74, which entered into force on 25 May 1980. 46 CFR Part 62 addresses, in part, the condition of periodically unattended machinery spaces and incorporates the principles contained in "Automated Main and Auxiliary Machinery; Supplemental Guidance On", COMDTPUB P16700.4, NVIC 6-84 and Enclosure (1) of "Automated Main and Auxiliary Machinery", COMDTPUB P16700.4, NVIC 1-69. Often, Part 62 is incorrectly presumed to apply only to machinery or electrical installations that reduce vessel manning requirements; it applies to all automatically or remotely monitored or controlled systems or equipment.

2. NVIC's 1-69,1-78, and 6-84. "Automated Main and Auxiliary Machinery; Supplemental Guidance On", COMDTPUB P16700.4, NVIC 1-69, and "Automated Main and Auxiliary Machinery", COMDTPUB P16700.4, NVIC 6-84, are effectively superseded by 46 CFR 62. Similarly, "Automation of Offshore Supply Vessels of 100 Gross Tons and Over", COMDTPUB P16700.4, NVIC 1-78 is superseded by 46 CFR 130. It is expected that these NVICs will be reviewed in the future, any still pertinent info will be transferred to this chapter of the Marine Safety Manual, and they will be cancelled.

3. Automatic Auxiliary Boilers (46 CFR 63).

a. General. 46 CFR 63 contains regulations for control systems for automatic auxiliary heating equipment, steam boilers, water heaters, fluid heaters, and electric storage tank water heaters. This part was

3.F.3 a. (cont'd) first published December 12, 1968. Prior to that date, only automatic steam boilers operating at pressures exceeding 30 psi, used for purposes other than propulsion, were covered by regulations under 46 CFR 162.026 (Requirements for Boilers, Auxiliary, Automatically Controlled, Packaged, for Merchant Vessels). In actual practice, portions of Subpart 162.026 had been applied to other heating equipment. Certain portions of 162.026 were used in Part 63; however, the preponderance of Part 63 requirements were new at that time.

b. Incinerators. Incinerators installed on U.S. Coast Guard certificated and inspected vessels must comply with Title 46 of the Code of Federal Regulations (46 CFR) Subpart 63.25-9. 46 CFR 63.25-9 requires that incinerators meet the standards in International Maritime Organization Resolution MEPC.76(40), be tested for its emissions at an independent laboratory acceptable to the U.S. Coast Guard, and also be type approved by the U.S. Coast Guard. Type approvals are conducted by the Marine Safety Center.

G. Electrical Systems.

1. Introduction.

a. Overview of Electrical Systems. Electrical regulations are provided to set forth uniform minimum requirements for electrical equipment and systems aboard vessels in accordance with the intent of various statutes, the International Convention for Safety of Life at Sea (SOLAS), and other treaties that contain requirements regarding electrical installations. These requirements are intended to ensure that electrical installations aboard vessels provide services necessary for safety under both normal and emergency conditions and protect passengers, crewmembers, and other persons from electrical hazards. In addition, environmental concerns have played a major role in the development of various sections of the Electrical Engineering Regulations. Navigation and Vessel Inspection Circulars (NVIC's) and the Marine Safety Manuals (MSM), Volumes I-X, COMDTINST M16000 (series), augment regulations with clarifications and explanations.

b. Purpose of MSM Guidance. The Electrical Engineering Regulations, 46 CFR Subchapter J, can be difficult to understand. Regulatory intent, equivalency information, inspections aids, and examples are not provided. This section of the MSM provides information to fill the void caused by the limitations of the regulations as they apply to electrical equipment and systems on merchant vessels and mobile offshore drilling units. It also promulgates information on equipment, systems, materials and methods that have been deemed by the Commandant (G-MSE) to provide an equivalent level of safety.

This guide's purpose is not to repeat the regulations, but to augment them. Nothing contained in this guide shall be taken as amending the Code of Federal Regulations, nor as limiting the authority of the Officer in Charge, Marine Inspection (OCMI) in the determination of acceptable materials, systems, and installation methods.

c. History. Since the first electrical installations on the passenger ships "CITY OF BERLIN" and "MENDOZA" in 1879, a complex set of standards and regulations has evolved to address the hazards presented and the benefits provided by electrical equipment and

3.G.1 c. (cont'd) systems. Domestically, early efforts involved the early Bureau of Marine Inspection and Navigation (predecessor to the Coast Guard's Marine Inspection Program) and the American Institute of Electrical Engineers (predecessor to the Institute of Electrical and Electronics Engineers). Internationally, these involved the individual classification societies, the Intergovernmental Maritime Consultative Organization (predecessor to the International Maritime Organization) and the International Electrotechnical Commission. In the last few decades, the number of standards-making bodies affecting the marine electrical community has increased significantly.

d. The Electrical Program. The Marine Inspection Program uses plan review, and on-site inspection to ensure that electrical installations are designed, built and maintained in a manner to promote the safety of the vessel, its crew and passengers. The Electrical Engineering Regulations provide uniform minimum requirements for electrical equipment and systems in accordance with the intent of various statutes, the International Convention for Safety of Life at Sea (SOLAS), and other treaties that contain requirements regarding electrical installations. These requirements are intended to ensure electrical installations aboard vessels provide services necessary to protect passengers, crewmembers and other persons from electrical hazards.

e. Electrical Safety. Electrical Safety on ships includes the prevention of shock, fire and panic.

On a steel hulled vessel, a person is usually walking on or touching ground at all times, and is usually within reach of power cables or electrical equipment containing lethal voltages. The currents that can flow from an energized conductor to ground can be very large, even in an ungrounded system. Currents as low as twenty-five thousandths of an ampere (25 milliamps) that pass through the heart can cause death. Currents of a non-fatal magnitude, or currents having a path to ground through other parts of the body can cause severe burns and injury. Minor shocks can also create severe secondary injuries when muscles contract involuntarily.

Fire is the greatest dread of seamen, and electricity is one of the most frequent causes of fire. A fire hazard can exist wherever electrical potential is present, and on a ship, the electrical installation covers a far greater area than any other type of installation.

How can electricity start a fire? Current flowing through a conductor encounters resistance. This resistance generates heat. If the conductor is properly sized, the heat is harmlessly dissipated. Where the conductor is not adequate sized for the current, or where the heat generated by the current is prevented from properly dissipating, whether it is the normal current, an overload current, or a fault (high or low impedance) current, the heat can become excessive, and can start a fire in nearby combustible materials, such as cable insulation.

Electrically-caused fires most often involve wire and cable. Most vessels have many miles of cable run throughout the entire vessel spreading their risks to all locations. Whenever the protective

3.G.1 e. (cont'd) insulation of a wire or cable is damaged by heat, moisture, oils, corrosive materials, vibration, abrasion, or impact, or where faulty installation or operating conditions result in loose connections, the threat of fire exists.

Motors are also a frequent source of electrically-caused fires. Motor fires can be caused by overheating, such as would be caused by overloading, single phasing, inadequate ventilation, malfunctions, such as internal faults and arcing, and bearing failure caused by inadequate lubrication.

Proper shipboard electrical installations also help reduce or prevent panic during an emergency. Put an individual, such as a vessel passenger, in the dark, in a strange place, in threatening circumstances, and the stage is set for panic. Electrical installations are designed to keep the lights on, power vital equipment, and allow needed information to be passed to passengers and crew.

f. Regulations and References. The Electrical Engineering Regulations, 46 CFR Parts 110 - 113 (Subchapter J), contain the primary standards for the review of electrical installation on USCG certificated vessels. See Table 3G-1 for vessel types and their primary/ secondary applicable subchapter of the 46 CFR regulations.

Table 3G-1
Applicable Electrical Regulations

Vessel Type	Primary / Secondary Subchapter
MODU	I-A / J
Offshore Supply Vessels	L
Small Passenger Vessels > 150 passengers or with overnight accommodations >49 people.	K
Small Passenger Vessels Under 100 Gross Tons < 150 passengers or with overnight accommodations <49 people, > 6 passengers.	T
Passenger Vessels (100 GT or more)	H / J
Tank Vessels	D / J
Uninspected Vessels	C
Cargo & Miscellaneous Vessels	I / J

g. Maintenance of Standards. 46 CFR 110.10-1(b) lists the industry specifications, standards, and codes that are incorporated by reference and supplement the Electrical Engineering Regulations. For the most part, these standards are dynamic. Therefore, references and associated amendments are listed with publication dates to inform

3.G.1 g. (cont'd) the user of the official referenced standard. At times, that edition may not be the latest edition of the standard thus causing confusion within the industry. Since most standard changes often respond to an identified problem or hazard, and usually result in safer equipment, the USCG has allowed for equivalency determinations (46 CFR 110.20-1). In most instances, equipment constructed and tested in accordance with a more recent edition of a referenced document can be accepted as long as they provide a level of safety equivalent to that provided by equipment constructed and tested to the edition identified in the CFR.

2. Equipment.

a. Systems Approach. The Electrical Engineering Regulations are a combination of equipment and system requirements designed to ensure that electrical installations are both safe and functional. They consist of general requirements related to across-the-board "good marine practice," and specific requirements related to the various apparatus, their proper design, installation and use.

In years past, emphasis was placed on equipment design requirements, as the system was considered the sum of the components (equipment). Today, equipment quality has generally improved and manufacturers have become more aware of product safety and liability. Comprehensive industry standards now exist and are used for most apparatus. This is allowing the review emphasis to shift towards a systems approach. As indicated previously, evaluations of equipment should consider overall safety comparability. With today's limited resources for plan review and inspection, concentration should be on proper application of equipment, effect of failures on required system functions, and on vital safety features.

Emphasis should be on evaluating the "system" -

Is the apparatus enclosure appropriate for the location?

Is the fixture adequately grounded to reduce the shock hazard? -

Is the fixture enclosure fire retardant and not surrounded by combustibles?

Will the first upstream overcurrent device safely clear a fault in the fixture so that other parts of the electrical system are not needlessly affected?

If it is a vital safety system, is the failure indicated and an alternative or back-up provided?

Do the components go together?

This is the "systems" approach. This does not imply that individual equipment design details are not important, but stresses that where there are limiting constraints, the system should be given a higher priority.

A recent casualty can be used to illustrate the necessity of "systems" thinking. While working on a motor controller, a crew

3.G.2 a. (cont'd) member's screwdriver caused a short circuit. The upstream circuit breaker on the main board became damaged and did not open. Eventually, the generator circuit breaker tripped, but only after the switchboard had been destroyed, with the bus bars torn from their bases and internal components and wiring destroyed by fire. Two separate items, a faulty circuit breaker and the cleaning fluid used in the switchboard months before, were initially blamed. However, upon further analysis, improper system design features became suspect. The upstream circuit breaker probably did not clear the fault because it did not have adequate interrupting capacity for the available fault current. The switchboard was damaged because it was not braced for the available fault currents. The common denominator was the fault current analysis. The existing components were not appropriate for the system in which they were installed. The electrical plant was, either in the original design or during subsequent modifications, most likely considered an assembly of components. These components may have been acceptable if used within their design limitations, but were not adequate when used in a system with high available fault currents.

The systems approach usually begins with an analysis of the "one-line diagram" and it's supporting information. The plan review section of this chapter, 3.B.2.b(2), contains a "typical" shipboard electrical one-line diagram and index to the applicable requirements in 46 CFR Subchapter J, the National Electrical Code, IEEE-45, etc.

For electrical equipment on ships, it is not the intent of the regulations to require a separate class of "marine electrical equipment." The intent is to permit normal, off-the-shelf commercial and industrial equipment to the maximum extent practicable, with additional "marine" requirements only when needed. The acceptance of this type of equipment is made possible by careful consideration of equipment application, location and placement. Subchapter J contains general requirements for electrical equipment to ensure that passengers, crew, and other persons, and the vessel are protected from electrical hazards. It also ensures that equipment necessary under both normal and emergency conditions is located in a manner that allows for routine maintenance and testing, thus helping to ensure that the equipment will function properly when needed.

b. Location and Placement (46 CFR 111.01-3). Optimal equipment location should be sought. In general, electrical equipment should be located in as dry a location as practicable and electronic equipment located in a controlled environment. In evaluating location, both normal and abnormal conditions should be considered. Abnormal conditions include items such as piping leaks (overhead for lower pressures and "in the vicinity" for higher pressures). For more critical equipment, such as the main switchboard, the regulations provide specific construction and location details. Generally, equipment should be located where it would not be subjected to oil, vapors, steam or dripping liquids. However, where relocation is not practicable, or where additional safeguards are warranted, the equipment should be designed to withstand these influences. Equipment should also be located to minimize the risks to personnel when routine service is being performed.

c. Degrees of Enclosure (46 CFR 111.01-9). Where exposed to the weather, or in a space exposed to seas, washdowns, or similar

3.G.2 c. (cont'd) moisture, equipment must be in a watertight enclosure (NEMA 4 or 4X or IEC IP56). A watertight enclosure is one that does not leak when subjected to a specified hose or immersion test. Motors must be waterproof. Waterproof motors may experience some leakage when subjected to the hose test, however, the leakage must not hinder operation, or enter any oil reservoir, and provision must be made for automatic draining before the level becomes damaging. Where dripping liquids could fall on equipment, that equipment enclosure should be dripproof. Dripproof equipment is ordinarily designed to prevent falling drops of liquid or solid particles from interfering with the operation of the equipment when striking the enclosure downward at any angle from 0 to 15 degrees from the vertical. Some equipment is designed for angles up to 45 degrees. It should be verified during vessel inspection that electrical equipment is suitably located - away from damaging liquid (unless impracticable, in which case it must be suitably designed), and accessible for inspection, adjustment and testing.

d. Corrosion (46 CFR 111.01-11). The corrosiveness of the marine environment is well known, and protection can usually be accommodated at the design stage. Much of the equipment that finds its way to sea was originally intended for a commercial or industrial installation on land, and could quickly fail in a salt-water environment if additional precautions are not taken. For this reason, equipment located in the weather, or in other locations subjected to salt water, must be evaluated to ensure corrosion resistance. Not only must the enclosure be corrosion-resistant, but current-carrying components and internal parts whose failure would create an unsafe condition must also be corrosion-resistant.

e. Porcelain (46 CFR 111.01-13). Porcelain should not be used for lamp sockets, switches, etc. unless resiliently mounted. The concern is that rigidly mounted porcelain may fail under shipboard vibration and create a shock, fire or other hazard to the vessel and its personnel. Some off-the-shelf equipment, designed for typical land installations, only comes with rigidly mounted porcelain insulated components. In these instances, it may be necessary to add resilient mounts to the porcelain insulating material. Only in instances where porcelain failure would not create a hazard, or where there is data available to support a shipboard application, such as vibration and shock (impact) testing, should such rigid installations be evaluated for general safety equivalency.

f. Temperature (46 CFR 111.01-15). The present regulations assume an ambient temperature of 40 degrees Celsius (104° F), except for engine rooms, boiler rooms, and auxiliary spaces, which are assumed to be 50 degrees (122° F) (unless shown or designed to be less, in which case 40 degrees Celsius is assumed). There are, however, differences in national and international standards on assumed values of ambient temperatures. IEEE-45 allows for both 45 and 50 degree ambient temperatures for engine rooms, and allows switchboard apparatus (other than molded case circuit breakers) rated for 40 degrees to be used in 50 degree environments under some conditions (see Section 17.6 of IEEE-45). The American Bureau of Shipping's Rules assume a 45-degree ambient for engine rooms, but indicate that rotating machinery is to be rated for a 50 degree ambient. ABS is in agreement with the requirements in the IEC standards. In looking at the

3.G.2 f. (cont'd) differences in these standards, it must be remembered that assumed ambient temperatures reflect an opinion on the overall average or the typical or expected temperatures, not the range of temperatures that equipment may be expected to experience under all conditions of operation. It must also be remembered that although consensus opinions concerning a standard may change, the length of time it takes to implement those changes varies widely.

g. National Electrical Code. The National Electrical Code (NEC) indicates that for Code applications with Code wiring, the ampacity of the conductors connected to molded-case circuit breakers should be limited to that of 60 or 75 degrees Celsius wiring, even though the attached conductors may have a higher rating. Shipboard requirements in the Electrical Engineering Regulations do not impose this limit; such a limitation does not apply on ships and MODUs. Ship systems do not use Code wiring, and are not typical of common applications addressed by the Code. Cable constructed to the electrical engineering regulations have ampacities based upon rated conductor temperatures up to 100 degrees Celsius. Shipboard cables may be connected to circuit breakers without consideration of the NEC limitation.

3. Grounded Systems and Ground Detection (46 CFR 111.05).

a. Equipment Ground (46 CFR 111.05-3). The term "grounding" is often misunderstood due to use in several different concepts. A basic understanding of the various uses is important. There are three basic applications of "grounding" associated with safety of personnel or protection of electrical equipment. These are:

(1) The grounding of metal frames or housings of electrical equipment (chassis ground);
(2) The grounding of the neutral current-carrying conductor of an electrical distribution system; and
(3) The grounding of an electrical source of power in such a manner that the earth (or its substitute such as the hull) is used as a current-carrying conductor.

The first application is one of the most important uses of grounding to protect personnel from electric shock. Fixed equipment is usually grounded by its method of attachment to the vessel. Isolation mounted equipment is usually grounded by a flexible grounding strap between the enclosure and the hull. Portable equipment is usually grounded with a grounding conductor in the supply cable. This should connect the equipment housing to the vessel's hull. Under normal conditions, the housing is not energized. However, internal insulation breakdown or other failure can bring energized components in contact with the housing. If the housing were not grounded, the voltage on the housing could equal the voltage of the power source, and a person touching the housing would be exposed to this voltage. Grounding the equipment reduces the shock hazard. Conductors used to ground equipment are called grounding conductors. On an extension or portable tool cord, this is the green insulated conductor. Portable equipment such as power tools that are identified as "double insulated" need not have a grounding conductor in the attachment cord. These items have a basic (functional) insulation system and a supplemental (protective)

3.G.3 a. (cont'd) insulation system, with the two insulation systems physically separated so that they are not simultaneously subjected to the same deteriorating influences.

The second application is the intentional grounding of a single pole or terminal of the power supply of an electrical distribution system. This is accomplished by connecting a low resistance conductor from the pole to the ground (the hull).

The purpose of grounding one of the conductors is to limit the voltage that the system can be subjected to under certain fault conditions. Grounding can also be accomplished through a resistor (resistance grounding) or through an inductor (inductive grounding). In these methods, the resistor or inductor is used to limit the line-to-ground fault current; these require special considerations and analysis.

It is important that a grounded system have only a single point of connection to the hull, regardless of the number of power sources, and that it be accessible for inspection. Multiple grounding points could create potentially dangerous and damaging circulating currents through the hull. The neutral of each generation and distribution system must be grounded at the generator switchboard, except for the neutral of an emergency power generation system. This must have no direct connection to ground at the emergency switchboard. The emergency switchboard neutral bus must be permanently connected to the neutral bus on the main switchboard, and there must not be any fuse, switch, or circuit breaker that opens the neutral conductor of the bus-tie feeder.

Grounded distribution systems of less than 3000 volts line-to-line are prohibited on tank vessels by SOLAS. The concern is that fault currents going through the hull may cross discontinuities, such as riveted joints, ladders, etc., and there may be an arc and subsequent ignition of flammable vapors. Systems greater than 3000 volts may be grounded provided any resultant fault current would not flow through the cargo tank area. This is usually not a problem as electrical loads operating at these voltages (other than possibly a bow thruster) are typically not located separate from the machinery space.

On some merchant vessels, the electrical distribution systems are ungrounded. There is no intentional connection to ground. This is primarily for circuit reliability. The electrical system can sustain damage that "grounds" one of the conductors and still function (i.e. provide continuity of service).

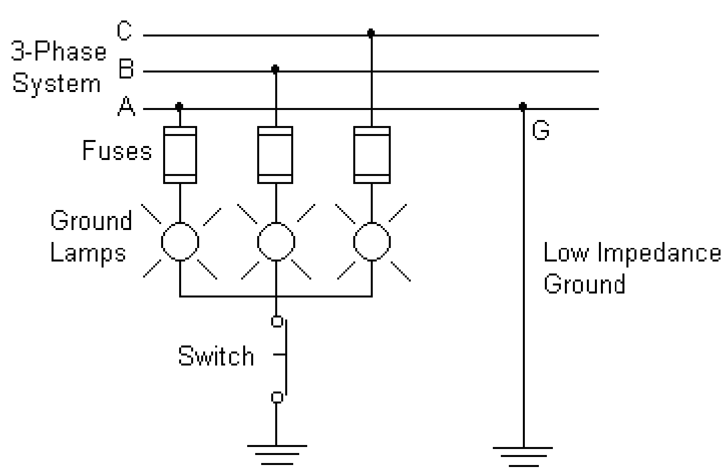
There is often the assumption that a person can contact an energized conductor in an ungrounded system, and not receive an electric shock since there is no return path for the current to flow back to the distribution system. Such an assumption can lead to fatal consequences. In practical applications, there is always a return path, and a system is always "grounded" to a certain extent. Paths exist through deteriorated or damaged insulation, and moisture, salt and other contaminants that are ever present. The issue is one of "degree." In ungrounded alternating current systems there is always a capacitance between conductors and between conductors and ground.

3.G.3 a. (cont'd) This impedance can effectively "ground" an intentionally ungrounded system.

The third application is the grounding of a power supply and an electrical load such that the hull is used as a normal current-carrying conductor. This is commonly referred to as "hull return" and is prohibited on vessels except for systems listed in 46 CFR 111.05-11. Acceptable examples include impressed current cathodic protection systems and limited and locally grounded systems such as engine cranking batteries. Insulation level monitoring systems and welding systems (on other than tank vessels) may also use the hull as a current-carrying conductor. One of the problems with hull return pertains to galvanic corrosion. Where the hull current passes through a welded joint or a joint of dissimilar metals, corrosion can occur.

b. Ground Detection (46 CFR 111.05-21, 23). Grounds can be a source of fire and electric shock. In an ungrounded system, a single ground has no appreciable effect on current flow. However, if low resistance grounds occur on conductors of different potentials, very large currents can result. In a grounded system, a single low impedance ground can result in large fault currents. To provide for the detection of grounds, the regulations require that ground detection means be provided for each electric propulsion system, each ship's service power system, each lighting system, and each power or lighting system that is isolated from the ship's service power and lighting system by transformers, motor generator sets, or other device. This indication need not be part of the main switchboard but should be co-located with the switchboard (i.e. at the engineering control console adjacent to the main switchboard). The indication may be accomplished by a single bank of lights with a switch which selects the power system to be tested, or by a set of ground detector lights for each system monitored.

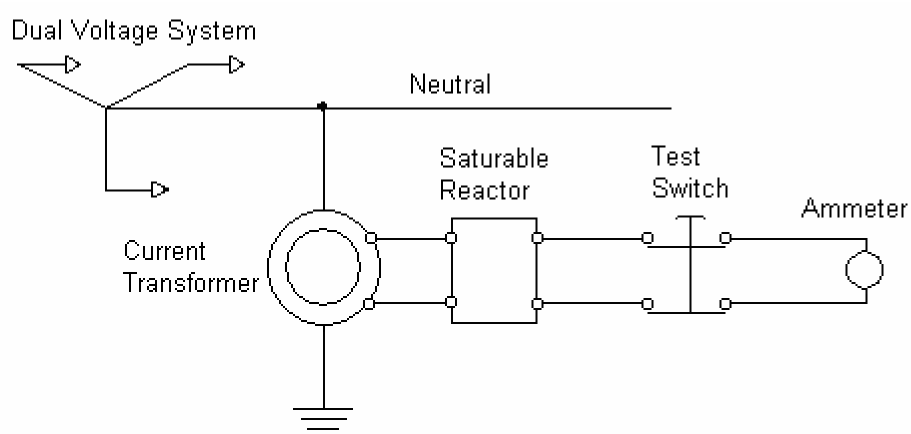
In an ungrounded three-phase system, ground detection lamps are used. The ground lamps are connected in a "wye" configuration with the common point grounded. A normally-closed switch is provided in the ground connection. This is illustrated in the figure below.



If no ground is present on the system, each lamp will see one-half of the phase-to-phase voltage and will be illuminated at equal

3.G.3 b. (cont’d) intensity. If line "A" is grounded at point "G" by a low impedance ground, the lamp connected to line "A" will be shunted out and the lamp will be dark. The other two lamps will be energized at phase-to-phase voltage and will be brighter than usual. If a low resistance ground occurs on any line, the lamp connected to that line will be dimmed slightly and the other two lamps will brighten slightly The switch is provided to aid in detecting high impedance grounds that produce only a slight voltage shift. When the ground connection is opened by the switch, the voltage across each lamp returns to normal (phase voltage) and each lamp will have the same intensity. This provides a means to observe contrast between normal voltage and voltages that have shifted slightly. Lamp wattages of between 5 and 25 watts when operating at one-half phase-to-phase voltage (without a ground present) have been found to perform adequately, giving a viewer adequate illumination contrast for high impedance grounds. Should a solid ground occur, the lamps will still be within their rating and will not be damaged. For lesser grounds, the lumen output of the lamps will vary approximately proportional to the cube of the voltage. This exponential change in lamp brightness (increasing in two and decreasing in one) provides the necessary contrast.

On grounded dual voltage systems, an ammeter is used for ground detection. This ammeter is connected in series with the connection between the neutral and the vessel ground. To provide for the detection of high impedance grounds with correspondingly low ground currents, the regulations specify an ammeter scale of 0 to 10 amperes. However, the meter must be able to withstand, without damage, much higher ground currents, typically around 500 amperes This feature is usually provided by the use of a special transducer such as a saturable reactor in the meter circuit. Some ammeters use a non-linear scale to provide for ease in detecting movement at low current values. An example of this is shown in the figure below.



Other types of solid-state devices are becoming available that can provide ground detection. They should not be prohibited, but should be evaluated to determine that they are functionally equivalent to the lights and ammeters historically used. Some systems also include a visual and/or audible alarm at a preset level of ground current.

3.G.3 c. Overcurrent (46 CFR 111.05-37). In the case of over current devices that are heat dependent, such as a fuse or the thermal trip on a circuit breaker, temperature is important, as it relates to the time it takes to remove an undesirable condition (overload). A device in a temperature lower than it is rated for will be slightly slower to trip on overload. If the temperature is higher, it will trip more quickly. In specific instances, either of these could be the undesired event. In the fault current range, the time effect is negligible. It should also be noted that many of these mass produced devices do not perform uniformly.

4. Power Supply (46 CFR 111.10).

a. Capacity. Determining the number and size of generating sets needed for a vessel requires a careful analysis of the normal and maximum demands during various phases of operation, including at sea, maneuvering, and in port.

Also, any special or unique operational considerations should be addressed. It is the intent of the regulations to ensure all normal "ship's service" loads can be kept energized with the largest generator out of operation, and without use of the emergency generator. It is not the intent of the regulations to ensure that the vessel can continue to perform an industrial function, such as drilling or dredging, with a generator in reserve. Ship's service loads are defined in detail in 46 CFR 111.10-1.

Of special note is that refrigerated container loads are considered "ship's service" loads. This is so cargo preservation attempts will not require sacrificing the more traditional ship's service loads should an operating generator fail. Other arrangements, such as a separate generating system, or a reefer load-shedding/load management system can provide an equivalent level of safety.

Procedures for conducting a thorough load analysis, typical ship's service operating load factors, and a sample load analysis are contained in section 3.B.2.b(3)(d) of this chapter.

b. Main Engine Dependent Generators. The most commonly used prime movers for ship's service generators are dedicated diesel engines and steam turbines supplied by the propulsion boiler(s). However, due to escalating fuel costs, owners and designers are always looking for less expensive means to provide the necessary electric power. Shaft-driven generators, power take-off (PTO) generators, and waste heat driven turbogenerators offer flexibility and greater efficiency. In many cases, however, they are constrained to certain main engine speed and power operating ranges.

SOLAS states that the arrangements of the ship's main source of power shall be such that the ships service loads can be maintained regardless of the speed and direction of the main propelling engines or shafting. This is reflected in 46 CFR 111.10-4(b) and (c), which require that ship's service electrical power be provided continuously, regardless of propulsion shaft speed or direction. In the worst case, this means that an "engine stop" or "full astern" command on the bridge propulsion control lever while operating at the

3.G.4 b. (cont'd) minimum engine speed for full generator output must not result in interruption of ship's service power.

Generators may be mechanically driven by the main diesel engine directly by the line shaft, by means of a PTO from the engine, or through intermediate gearing. Because changes in main engine speed would normally result in changes in the generator speed (and, therefore, frequency), a variety of methods has been developed to maintain constant frequency. These include the operation of the main diesel engine at a constant speed with the pitch of a controllable pitch propeller independently controlled, the use of a constant speed gear drive to give a constant output shaft speed over a range of input shaft speeds, and the application of a static rectifier-inverter combination to transform variable frequency AC to constant frequency AC.

Waste heat energy from the main diesel engine can be recovered in an exhaust gas boiler to generate low pressure steam to drive a turbogenerator. This generator can be operated only when sufficient exhaust heat is available, so start-up and shutdown are usually manually initiated. To optimize the recovery of exhaust heat, a generator loading control system may be used with load-sharing and speed (governor) controls to maximize turbogenerator loading when operating in parallel with other generators. Any main engine or waste heat driven generator which is not capable of providing power under all operating conditions, including maneuvering and in port, cannot be counted towards the required ship's service generating capacity. Such a generator may however, be provided as a supplemental generator. In any case, one of the required generators must be independent of the main propelling engines and shafting.

Where a supplemental generator is used to supply power for ship's service loads, it must provide a continuous and uninterrupted source of power under normal operational conditions, including any speed change or throttle movement. Automatic start-up of and load transfer to a standby diesel generator must be provided to prevent power interruptions when conditions are such that the supplemental generator is unable to supply the ship's service load. A finite time is required to start, synchronize, and parallel a standby diesel generator, and the main engine-driven generator must remain on line until the standby generator has assumed the load. A signal from the propulsion control and a shaft speed signal may be used to automatically initiate connection of the standby generator. Once a throttle change has been made, the time required for the main engine to slow to the point where the generator cannot supply the ship's service load depends on the original speed as well as the coast-down characteristics of the hull and propulsion plant. In many cases, the coast-down time for a two-stroke slow speed main diesel engine is long enough to allow the standby generator to assume the load without power interruption. If it is not, the disconnection of the shaft or PTO generator must be delayed. To prevent power interruptions from occurring, the speed of the main engine may be automatically held at or above the lower operating threshold for generator operation for approximately 10 seconds. This delay, automatically activated only when needed, is considered to be comparable to the time necessary for crew response to maneuvering bells in a manned engineroom. Since the typical main engine dependent generator installation employs

3.G.4 b. (cont'd) automated start and synchronization controls for the standby generator(s), careful design and detailed review to the requirements of 46 CFR Part 62 is generally required to ensure compliance with 46 CFR 111.10-4.

c. Ship's Service Supply Transformers. The regulations state that where transformers are used to supply the ship's service distribution system, there must be at least two separate ship's service supply systems. The intent is to duplicate supplies to the ship's service switchboard, as is done with generating sets. This would normally exist on a vessel generating at a higher voltage, such as 600 or 4160 volts. It is not the intent, nor is it required, that transformers fed by the ship's service switchboard, such as 460/120 volt transformers be duplicated.

Each transformer must have the capacity to supply the ship's service loads. The duplicated supply should consist of transformers, overcurrent devices, and cables. Automatic changeover upon a transformer failure is not required. It could be inferred from the transformer/generator analogy of SOLAS 11-1/45, that automatic transformer transfer is required by the SOLAS 11-1/53 requirements for automatic starting and connection of a stand-by generator. That analogy has, however, not been applied to transformers since the precise wording of Reg. 53 addresses generators, and not "essential parts of the electric supply system." Additionally, the reliability and availability of a "static" transformer, and its cable and overcurrent device is much better than a rotating generator, its prime-mover and control system. Transformer faults are rare, and the requirement for duplication is considered from a "come-home" standpoint. (This is similar to the requirement for a split bus arrangement on a ship with a large electrical system. There is no requirement to automatically disconnect switchboard sections and attempt to maintain power upon a switchboard fault. The requirement for splitting the bus is to provide the capability for onboard engineers to be able to isolate a fault and restore limited service.)

5. Generator Construction and Protection (46 CFR 111.12). Generator excitation, construction, and voltage regulation, should meet ABS Rules as outlined in 46 CFR 111.12-1. Generator protection, provided by power circuit breakers, should meet the specific requirements in the Electrical Engineering Regulations. There are many types of circuit breaker trips: inverse time, instantaneous, reverse-power/current, under and overvoltage, ground fault, under and over frequency, and trips operated by auxiliary contacts. 46 CFR 111.12-11 specifies the required trips for generator circuit breakers. The inverse time trips are devices that open the circuit breaker in a time that relates to the amount of overcurrent. The greater the overcurrent, the quicker they open the circuit. They are adjustable and should be set so that downstream or feeder breakers have had the opportunity to open and clear faults on the feeder circuits. Instantaneous trips are quick-acting devices that have no intentional time delay in opening the circuit breaker under high-level currents. Instantaneous trips are not permitted for generators unless three or more generators can be paralleled. This is to provide continuity of service under a fault condition. Reverse-power or reverse current trips are required where generators can be paralleled. These are quick-acting devices that will open the circuit of a generator that has current from other generators feeding into it. Additional information is provided on circuit breakers.

3.G 5. (cont’d) Generator overcurrent protective devices must be on the ship's service switchboard and the switchboard and a generator must be in the same space. An adjacent dedicated switchgear and SCR room on a MODU, and a control room inside the machinery casing are not considered separate spaces even though they may be separated by a watertight bulkhead. In unusual installations where the switchboard and a generator are separated by a bulkhead or enclosure that is not required for either subdivision or fire protection purposes, the spaces may also be treated as a single space for the purpose of this requirement. Additional precautions may be needed, such as current sensing at the generators that, upon sensing excessive overcurrent, removes excitation and shuts down the prime mover.

The Marine Engineering Regulations contain the requirements for prime movers in 46 CFR 58.10. Additional requirements for prime movers for emergency generators are found in 46 CFR 112.50, and are discussed later in section 3.G.19. Each diesel engine prime mover must have an overspeed device that is independent of the normal operating governor and is adjusted so that the speed cannot exceed the maximum rated speed by more than 15%. Additionally, the prime mover should automatically shut down upon loss of lubricating oil pressure to the generator bearings. These shutdowns should be tested at each inspection for certification.

6. Batteries and Battery Installations (46 CFR 111.15).

a. Electrical Storage Batteries. Electrical storage batteries have many shipboard applications, including engine starting, temporary or final emergency power source, and backup power supply. In general, the requirements of 46 CFR Subpart 111.15 are applicable to all such battery installations. Note that storage batteries used for required emergency power and lighting systems must comply with Subpart 112.55.

b. Battery types & Equivalencies. Battery types & equivalencies: Batteries may be classified according to the chemical composition of their plates and/or the type of electrolyte solution -- thus the terms lead-acid, alkaline, nickel-cadmium (Ni Cad), etc. A nickel-cadmium battery is a particular type of alkaline (electrolyte) battery. Storage batteries other than the lead-acid or alkaline type may be accepted provided they do not spill electrolyte when the battery is inclined at 30 degrees from the vertical, are suitably constructed to comply with 46 CFR 111.15-2(a), and generate hydrogen at a rate not to exceed that of an equivalent lead-acid battery installation under worst case conditions.

c. Gel-Cell Batteries. Gel-Cell Batteries may be preferable due to lower maintenance than wet-cell batteries. Since there is no need to check and add electrolyte to the Gel-Cell batteries, as is required with the wet-cell batteries, the use of Gel-cell batteries reduces the exposure of personnel to this potentially hazardous maintenance activity. Additionally, storage of the electrolyte, a hazardous material, is eliminated. The gel-cell battery requires extra care with regard to charging and is typically charged with an automatic temperature-sensing, voltage-regulating battery charger. Caution must be observed when determining the correct charging system as improper charging can cause damage to the battery. Failure of a gel-cell battery installed in an emergency or vital system such as an emergency generator could have an adverse operational impact.

3.G.6 d. Hazardous Locations. The Electrical Engineering Regulations categorize battery installations into one of three types, based upon the power output of the battery charger and the corresponding amount of highly flammable hydrogen gas, which may be generated. Each room, locker, and box containing storage batteries must be arranged or ventilated to prevent the accumulation of this gas. Large battery installations may be located only in a dedicated battery room or in a box on deck. Such a battery room is considered to be a hazardous location; only electrical equipment approved for use in a Class I, Division 1, Group B location may be used in such a battery room.

The regulations do not define the hazardous area as extending to a radius of 10 feet (3 meters) from doors, hatches, or other openings into the battery room. However, the use of explosion proof or intrinsically safe electrical equipment or apparatus and the avoidance of ignition sources near such openings are recommended.

Where flammable gases or vapors may be present, such as on the drill floor of a Mobile Offshore Drilling Unit or in the pumproom of a tankship, special precautions must be taken to ensure that electrical equipment is not a source of ignition. Subpart 111.105 of the Electrical Engineering Regulations contains the requirements for electrical equipment and wiring in locations where fire or explosion hazards may exist. In these locations, it is necessary to exercise more than ordinary care with regard to the selection, installation, and maintenance of electrical equipment and wiring. A primary objective of design should be to minimize the amount of electrical equipment installed in hazardous locations. Through the exercise of ingenuity in the layout of electrical installations for hazardous locations, it is frequently possible to locate much of the equipment in less hazardous or in non-hazardous areas and thus reduce the amount of special equipment and installations required.

The Electrical Engineering Regulations incorporate by reference Articles 500 through 505 of the National Electrical Code, with the exceptions listed in 46 CFR 111.105-3. Non-explosion-proof equipment can be allowed in accordance with the NEC.

The Electrical Engineering Regulations also incorporate by reference the IEC 60079-XX "Electrical apparatus for explosive gas atmospheres" series of standards. The big difference between the two referenced ways of classifying a hazardous location is the use of Zones (IEC) and Divisions (NEC). In 1998, the NEC Article 505 adopted the alternative way to classify hazardous areas and included Class I Zones 0, 1 & 2 locations.

The obvious main difference between the Zone and Division systems are the wiring practices and the more prevalent use of plastics in the Zone system. Another notable difference is the size of the equipment used in hazardous areas. For example, NEMA starters are larger and built for easy selection, use and maintenance. IEC starters, on the other hand, are built smaller, minimizing the use of materials but requiring much more attention to selecting the correct starter for the specific application.

e. Classification of Battery Installations. The classification of battery installations based upon the power output of the charger may

3.G.6 e. (cont'd) not be appropriate for some types of batteries (such as gel-cells) which generate very little to no hydrogen gas. In such cases, the quantity of gas generated should be compared to the amount released by lead-acid batteries to determine whether the installation should is large, moderate, or small. The battery manufacturer, designer, or shipbuilder should provide this comparison to the USCG.

Sealed batteries, which release gas only when a relief valve opens following an over-voltage charge, may also be accepted. However, their installation must consider the over-charge condition, and allow released gas to be safely dissipated. The lining requirement of 46 CFR 111.15-5(g) allows the acceptance of plastic battery trays and liners certified by the manufacturer as resistant to the corrosive effects of the battery electrolyte. Battery chargers that meet UL 1564 (Industrial Chargers) plus the marine supplement to UL 1236 may be accepted as equivalent to those meeting UL 1236.

f. Emergency Power Batteries. Automotive-type batteries are not suitable for emergency power applications, as indicated in NEC Article 700-12. Automotive batteries are designed for frequent, short duration, high current loading; emergency power systems usually operate less frequently, for longer periods, at lower current levels. Automotive batteries also have a shorter life (3 - 5 years) than lead-acid storage batteries designed for use in emergency power systems (15 - 20 years). Storage batteries for emergency power service have either a threaded stud or a rectangular blade for connection of a bus link. They usually have external cell connectors. Automotive batteries have either side terminals that can accept a threaded bolt, or top round posts for an automotive battery cable.

7. Transformers (46 CFR 111.20).

a. Sectionalized And Redundant Transformers (46 CFR 111.10-9). Sectionalized buses increase the ability to provide ship's service power in the event of a casualty to part of the switchboard. On a single voltage level system (i.e., where generated voltage is the ship's service switchboard voltage), the devices used to connect the sections of the buses must be manually operable. In a dual level system, (i.e., in which the generators connect to a medium-voltage bus which in turn supplies the low-voltage ship's service switchboard) at least two transformers or transformer banks are required by 46 CFR 111.10-9. If the medium-voltage bus is required to be sectionalized and the total capacity of these transformers exceeds 3000 KW, the low-voltage ship's service switchboard must also be subdivided. On a dual level system, automatic control of the sectionalizing may be permitted when it is part of a load management system allowing for increased system flexibility.

b. Transformers – Protection (46 CFR 111.20-15). The overcurrent protection for each transformer is required by 46 CFR 111.20-15 to meet Article 450 of the NEC or IEC 60092-303. The transformer overcurrent protection specified in Section 450-3 is intended to protect the transformer alone; the primary and secondary conductors may not be adequately protected. Be careful to ensure that conductor protection is provided. Note that where the primary feeder to the transformer is provided with overcurrent protective devices that are set per section 450-3, it is not necessary to install an individual

3.G.7 b. (cont'd) overcurrent device at the transformer. The primary conductors must then be sized so that their ampacity is greater than or equal to the rating or setting of the primary overcurrent protective device(s); see 46 CFR 111.50-3(a), (b), and 111.50-5(a). Secondary conductors supplied by a transformer must be protected in accordance with their ampacity. The secondary conductors of a single voltage single-phase transformer which satisfies the requirements of 46 CFR 111.50-5(a)(4) do not require overcurrent protection at the supply (the transformer) to the secondary side conductors. Aluminum-wound transformers are acceptable. They should be fully encapsulated by the manufacturer and all connections should be made in accordance with the guidelines for aluminum current-carrying parts in section 3.G.8 of this guide. See the next section for full load current ratings for single-phase and three-phase transformers.

c. Miscellaneous Tables.

Current Rating, Rectangular Bus Bars on Edge, 50 C Rise, IEEE 45-1983, A27 Single Bars in Parallel, Copper		
SIZE (inches)	DC	AC, 60HZ
3/4 x 1/8	250	250
1 x 1/8	330	330
1-1/2 x 1/8	500	500
1-1/2 x 3/16	580	570
2 x 3/16	760	745
1 x 1/4	490	480
1-1/2 x 1/4	685	675
2 x 1/4	920	900
3 x 1/4	1380	1280
4 x 1/4	1730	1650
5 x 1/4	2125	2000
6 x 1/4	2475	2300
8 x 1/4	3175	2875

Minimum Switchboard Spacing (inches)			
	LIVE PARTS, OPP. POLARITY,		BETWEEN LIVE PARTS & GROUNDED
Voltage	Over Surface	Thru air	Dead metal
125V or less	3/4	1/2	1/2
126V – 250V	1 – 1/4	3/4	1/2
251V – 600V	2	1	1

From NEC Table 384-26

Neutral Grounding Conductors, AC Systems	
A.W.G. OF LARGEST GENERATOR CONDUCTOR OR EQUIVALENT FOR PARALLEL	A.W.G. OF GROUND CONDUCTOR
Up to #2	#8
#2 - #0	#6
#0 - 3/0	#4
3/0 – 350 MCM	#2
350 MCM – 600 MCM	#1
600 MCM – 1100 MCM	2/0
Greater than 1100 MCM	3/0

See 46 CFR 111.05-31(b).

3.G.7.c (cont'd)

Generator Continuous Full Load Ampere Ratings. 3 - Phase 0.8 Power Factor													
		115%		115%		115%		115%		115%		115%	
KW	KVA	208V	FLA	230V	FLA	240V	FLA	460V	FLA	480V	FLA	600V	FLA
5.0	6.3	17.5	20	15.8	18	15.2	17	7.9	9	7.6	9	6.1	7
7.5	9.4	26.1	30	23.6	27	22.6	26	11.8	14	11.3	13	9.0	10
10.0	12.5	34.7	40	31.4	36	30.1	35	15.7	18	15.0	17	12.0	14
15.0	18.7	52.0	60	47.0	54	45.0	52	23.5	27	22.5	26	18.0	21
20.0	25	69.4	80	62.8	72	60.1	69	31.4	36	30.1	35	24.1	28
25.0	31.3	87.0	100	78.6	90	75.3	87	39.1	45	37.6	43	30.1	35
30.0	37.5	104.1	120	94.1	108	90.2	104	47.1	54	45.1	52	36.1	42
35.0	50.0	138.8	160	125.5	144	120.3	138	62.7	72	60.1	69	48.1	55
40.0	62.5	173.5	200	156.9	180	150.3	173	78.4	90	75.2	86	61.1	70
45.0	75.0	208.2	239	188.3	217	180.4	207	94.1	108	90.2	104	72.2	83
50.0	93.8	260.4	300	235.4	271	225.6	259	117.7	135	112.8	130	90.3	104
60.0	125.0	347.0	399	313.8	361	300.7	346	156.9	180	150.4	173	120.3	138
75.0	156.0	433.0	498	391.6	450	375.3	432	195.8	225	187.6	216	150.1	173
80.0	187.0	519.1	597	469.4	540	449.8	517	234.7	270	224.9	259	179.9	207
100.0	219.0	607.9	699	549.6	632	526.7	606	274.8	316	263.3	303	210.7	242
125.0	250.0	694.0	798	627.6	722	601.4	692	313.8	361	300.7	346	240.6	277
150.0	312.0	866.1	996	783.2	900	750.5	863	391.6	450	375.3	432	300.2	345
175.0	375.0	1040.1	1196	941.3	1082	902.1	1037	470.7	541	451.1	519	361.0	415

Notes:
(1) Generator cables shall be capable of carrying at least 115 percent generator continuous F.L.A. (see 46 CFR 111.60-7).
(2) Generator circuit breaker long time overcurrent trip shall not exceed 115 percent generator continuous F.L.A. (see 46 CFR 111.12-11).
(3) KW = KVA * PF
(4) $\text{Amperes} = \dfrac{\text{KVA} \times 1000}{\text{Volts} \times 1.732}$

Transformer Full Load Currents. 3-Phase Transformers Voltage (Line to Line)						
KVA Rating	208	240	480	800	2400	4180
3	8.3	7.2	3.6	2.9	0.72	0.415
6	16.6	14.4	7.2	5.8	1.44	0.83
9	25	21.6	10.8	8.7	2.16	1.25
15	41.6	36.0	18.0	14.4	3.6	2.1
30	83	72	36	29	7.2	4.15
45	125	108	54	43	10.8	5.25
75	208	180	90	72	18	10.4
100	278	241	120	96	24	13.9
150	416	360	180	144	36	20.8
225	625	542	271	217	54	31.2
300	830	720	360	290	72	41.5
500	1390	1200	600	480	120	69.4
750	2080	1800	900	720	180	104
1000	2775	2400	1200	960	240	139
1500	4150	3600	1800	1440	360	208
2000	5550	4800	2400	1930	480	277
2500	6950	6000	3000	2400	600	346
5000	13900	12000	8000	4800	1200	694
7500	20800	18000	9000	7200	1800	1040
10000	27750	24000	12000	9600	2400	1366

3.G.7.c (cont'd)

For other KVA Ratings or Voltages : Amperes = $\frac{\text{KVA x 1000}}{\text{Volts x 1.732}}$

Full Load Currents.						
Single Pase Transformers Voltage						
KVA Rating	120	208	240	480	600	2400
1	8.34	4.8	4.16	2.08	1.67	0.42
3	25	14.4	12.5	6.25	5.0	1.25
5	41.7	24.0	20.8	10.4	8.35	2.08
7.5	62.5	36.1	31.2	15.6	12.5	3.12
10	83.4	48	41.6	20.8	16.7	4.16
15	125	72	62.5	31.2	25.0	6.25
25	208	120	104	52	41.7	10.4
37.5	312	180	156	78	62.5	15.6
50	417	240	208	104	83.5	20.8
75	625	361	312	156	125	31.2
100	834	480	416	208	167	41.6
125	1042	800	520	260	208	52.0
167.5	1396	805	698	349	279	70.0
200	1666	960	833	416	333	83.3
250	2080	1200	1040	520	417	104
333	2776	1600	1388	694	555	139
500	4170	2400	2080	1040	836	208

For other KVA Ratings or Voltages : Amperes = $\frac{\text{KVA x 1000}}{\text{Volts}}$

8. Switchboards (46 CFR 111.30 – 25 & 111.30-27).

a. Location. SOLAS II-1/42.1.3 and 43.1.3 and 46 CFR 112.05-5(e) all state that the emergency generator room and a category A machinery space should not be adjoining, except where other arrangement is not practicable. Note that the CFR specifies the spaces will not be “adjoining”, SOLAS requires not “contiguous”, both indicating the spaces will not border each other horizontally or vertically. The intent is to maintain the integrity of the emergency electrical distribution system if there is a fire, flooding, or other casualty in the main machinery space. When the arrangement has been shown to be impractical, the installation of an A-60 bulkhead between the emergency generator room and the category A machinery space has been accepted. It is recommended that the steel bulkhead be insulated to A-60 on both sides. Any contiguous boundary between the emergency generator room and any category A machinery space or space containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard must be avoided.

b. Removable Breakers (46 CFR 111.30-4). The Electrical Engineering Regulations require molded-case circuit breakers on switchboards to be mounted so that the breaker can be removed from the front without first unbolting the bus or cable connections or de-energizing the supply to the breaker. The intent of this requirement is to make possible the safe removal of a circuit breaker for repair or replacement without de-energizing other essential loads. This

3.G.8 b. (cont’d) requirement is for circuit breakers in ship's service switchboards; removable or draw-out breakers are not required for dedicated industrial switchboards, but are recommended for safety. Where the main ship's service bus is subdivided into two sections, a comparable level of safety can be provided by an arrangement where all circuits necessary for the safe navigation of the vessel can be supplied by either section of the bus. This would allow for de-energizing one section without the loss of essential loads. Note that although the Subchapter J requirement to sectionalize the main bus is not applicable to Mobile Offshore Drilling Units, self-propelled MODU's seeking an IMO MODU Code certificate must meet this requirement (MODU Code Chapter 7, Section 9).

c. Bus Bars (46 CFR 111.30-19). Each bus must be sized so its rating is not less than the capacity required in 46 CFR 111.30-19(a). [NOTE: Bus bars for motor control centers are to be rated per NEC 430-24.] Table A27 of IEEE Standard No. 45 (1983 edition, section 7.10 of IEEE 45 1998 edition) gives minimum bus bar sizes, based on the cross section and spacing required for the bus current rating and the allowable temperature rise.

Bus bars must be braced to withstand the mechanical strains imposed by inrush currents and the maximum available short-circuit current. These currents can generate electromagnetic fields of considerable magnitude. The mechanical forces resulting from these fields can bend the bus bars, shatter insulation, and physically tear the switchboard apart.

Switchboard manufacturers should indicate the fault current their boards are designed to withstand. The spacing between bus bars and bare metal parts within the switchboard must meet Section 384-26 of the National Electrical Code.

d. Aluminum Busbars. There has been continued interest in the use of aluminum as a bus bar material, due primarily to the relative costs of copper and aluminum. Both marine and shore industrial experience has shown that careful attention must be paid to materials, joint design, and quality of workmanship if unsatisfactory and unsafe aluminum bus bar installations are to be avoided. The switchboard regulations, in 46 CFR 111.30-19, refer to IEEE Standard No. 45 for bus bar installations Section 17.11 of IEEE-45 permits aluminum to be used in switchboards. The panelboard regulations are found in 46 CFR 111.40-1. Aluminum must only be used in applications and in a manner permitted by the regulations. Certain problems and properties associated with aluminum bus bars are discussed below. For vessels operating only in fresh water, the corrosion problem may be minimal; the other three problems are equally applicable to fresh water and saltwater service.

(1) Corrosion - Aluminum in contact with certain other metals, such as steel, forms a galvanic couple susceptible to accelerated corrosion in the marine environment. Aluminum alloys containing copper are particularly subject to corrosion in a damp salt atmosphere, even when not in contact with a dissimilar metal.

(2) Oxide Build-up - Most aluminum alloys form a hard, inert oxide coat whenever a fresh surface is exposed to air. This layer of

3.G.8.d (2) (cont’d) aluminum oxide has a high electrical resistance and can create a hot spot at connection points.

(3) Creep - Aluminum exhibits a phenomenon known as creep, which is a plastic deformation that occurs at stresses below yield strength. Periodic tightening of many types of aluminum connections is required to prevent connections from becoming loose. If connections do become loose, the surface contact area is reduced, permitting the oxide coat to form. This, in turn, causes high-resistance hot spots.

(4) Thermal Properties –
   (a) As the load increases, the bus bar temperature will increase and the bus bars will expand. The linear coefficient of thermal expansion of aluminum alloys is significantly larger than that for steel or copper. Provisions must be made in the design to account for these different expansion rates. High stresses can occur in aluminum-bodied connectors, especially when used with bolts of a dissimilar metal or which have thermal expansion characteristics different from those of the aluminum device.
   (b) The thermal conductivity of aluminum, while alloy dependent, is approximately half that of copper. Heat is not conducted away from a hot spot in aluminum as quickly as with copper.

The use of aluminum bus bars in switchboards, large switchboard-type panelboards, and motor control centers are generally acceptable. The design and practices recommended below, or equivalents, should be considered. Aluminum bus bars are generally not suitable for use in panelboards and motor controllers. The small size and scattered locations of many panelboards and controllers may discourage the periodic inspections which should be made to detect unsafe deterioration of aluminum bus bars and connections. The following design and assembly recommendations will help ensure a satisfactory installation of aluminum bus bars: All aluminum current carrying parts should be made of alloy 6101 or other alloy with a maximum of 0.1 percent copper. In areas of contact, the bus bars, including any copper bars, should be plated with silver, nickel, or tin after all drilling has been completed. This plating should be performed at the manufacturer's facility and not in the field. Copper cable or wire should be connected to the aluminum bus using plated compression-type terminal connectors. Where aluminum bodied connectors and fittings are used, they should be packed with oxide-inhibitor paste. These fittings should be suitable for use on aluminum. A shrinkable sleeve should be used to seal the wire to the terminal connector. A generous amount of joint compound should be applied to all joint surfaces before assembly to seal out air and improve corrosion resistance. A bead of compound should appear all around the edges of each joint when the connection is tightened. Excess compound squeezed out of the joint may be left as is or removed. Abrasive joint compounds should not be used on flat-bar connections. A plated copper bar or plated copper terminal fitting may be connected to a plated aluminum bar. The connection should be made with a plated steel bolt, plated Belleville spring washers, and wide series plated steel washers.

3.G.8 d. (cont’d) The Belleville washer should be installed with the crown or neck against the nut or bolt head and the concave side bearing on the flat washer. The nut should be tightened until the Belleville washer is just flat. An aluminum-to-aluminum connection may be made with either plated aluminum or plated steel bolts. If steel bolts are used, the recommendations of the paragraph above should be followed. Aluminum bolts should be made of a high strength aluminum alloy. Aluminum bolts, nuts, and washers should be made of an alloy containing not more than 0.1 percent copper.

A plug-in type circuit breaker should not be directly connected to an aluminum bus. Circuit breakers or fused switches may be attached to an aluminum bus if a bolt or plug arrangement is used with joint preparation as described above. The plug-in type circuit breaker may be used with a copper bus feeder. A plated bus bar surface should not be wire brushed or treated with abrasive cleansers prior to assembly.

e. Shore Power (46 CFR 111.30). Electrical shore power connections are not required by the Electrical Engineering Regulations. Where provisions are made to use shore power, the connection boxes and switchgear must meet 46 CFR 111.83 and 111.30-25(f) for AC switchboards or 111.30-27(f) for DC switchboards. As an alternative to the standard shore power connection box, the use of military specification (MILSPEC) hardware is acceptable. The use of reverse-power or reverse-current relays should be considered when shore power is used extensively. In addition, interlocks are recommended to prevent the paralleling of shore power with the ship's generators.

9. Power Semiconductor Rectifier Systems (SCRs 46 CFR 111.33).

a. Introduction. The term SCR refers to the solid state equipment for the conversion of alternating current to direct current which has been called a silicon controlled rectifier, semiconductor controlled rectifier, and semiconductor rectifier. Many electric propulsion systems, thrusters, and pieces of drilling machinery use DC motors in order to obtain more precise speed control. SCR's are the most common means of converting the ship's service AC power to DC. Solid state SCR power converters offer the advantages of high efficiency and low maintenance (compared to motor-generator sets), but are sensitive to heat and humidity and are frequently located in suitably air-conditioned spaces.

Subpart 111.33 is applicable to any SCR used as part of the vessel's electrical power distribution system. Small SCR's, which form part of utilization equipment, such as a semiconductor rectifier battery charger, need not meet these regulations.

b. Requirements. The intent of the regulations is to ensure that the continuity of power to equipment supplied by SCR's is not jeopardized by unsuitable SCR design or installation. An adequate means of heat removal is the primary concern. Due to the criticality of the propulsion system to the safe navigation of the vessel, additional requirements apply to SCR's in electric propulsion systems; see 46 CFR 111.33-11.

c. Check-Off List. SCR System Check-Off List:

3.G.9.c

(1) Meets the requirements of 46 CFR 111.33, and for a switchboard and/or electric propulsion installation.
46 CFR 111.30-11, -19, -21.
(2) Name plate data.
(3) Heat removal system.
(4) Cooling.
(5) lmmersed type with non-flammable liquid and no leakage with vessel inclined.
(6) Located away from heat sources.
(7) Temperature rating and operating range.
(8) Unrestricted air circulation if naturally cooled.
(9) Inlet air temperature within design limits.
(10) Loss of cooling shutdown.
(11) Inlet cooling water temperature.
(12) watertight or dripproof rectifier stack.
(13) Vent exhaust does not terminate in a hazardous area.
(14) Vent exhaust does not impinge on electrical equipment in enclosure.
(15) High temperature alarm or shutdown.
(16) SCR propulsion systems:
   (a) Meet ABS Section 35.84.4 (1983).
   (b) Current and current rate limiting circuit.
   (c) Overcurrent protection.
   (d) High temperature alarm set below shutdown temperature.
   (e) Internal overcurrent device coordination.
   (f) Blown fuse detection system.
   (g) In dry place.
(17) SCR motor control:
   (h) Overspeed trip; loss of load (series); loss of field (shunt).
   (i) Shunt motor field excitation interlock.

10. Electrical Propulsion (46 CFR 111.35-1). The reference to the ABS "Rules for Building and Classing Steel Vessels" in 46 CFR 111.35-1 is out-of-date. Sections 4-8-5/5.5, 4-8-5/5.11, 4-8-5/5.13, 4-8-5/5.17.8(e), 4-8-5/5.17.9, and 4-8-5/5.17.10 of the 2003 edition of the ABS Rules may be used for guidance, or section 4/3.5.3 of ABS Rules for Building and Classing Mobile Offshore Drilling Units as appropriate. The general provisions of the SOLAS II-1/31, 49, and 52 are applicable to all propulsion arrangements, including electric propulsion.

11. Panelboards (46 CFR 111.40).

a. Ratings. The current rating of a panelboard must not be less than the feeder circuit capacity. To meet 46 CFR 111.40-15, the load on any overcurrent device in a panelboard must not exceed 80 percent of that device's rating if the normal load duration is 3 hours or more. This requirement does not apply, however, when the panelboard and the overcurrent device are rated for continuous duty at 100% of the rating.

b. Location. The main switchboard is required by 46 CFR 111.12-11(g) and 111.30 to be located in a machinery space that contains at least one ship's service generator. This requirement is consistent with the SOLAS Amendments, Chapter 11-1, and Regulation 41.3. A control room that is located within the machinery casing or a dedicated switchgear and SCR room on a Mobile Offshore Drilling Unit, which is adjacent to and on the same level as the generator machinery space, is not

3.G.11 b. (cont'd) considered to be a separate space. Any such control room containing the main switchboard should, as far as practicable, be located so that the generator(s) are in sight and direct access to the generator(s) is facilitated. Each switchboard must be located in as dry a location as possible. Dripshields are required by 46 CFR 111.30-5(b). An equivalent installation is a switchboard that extends to the overhead and which cannot be subjected to leaks or falling objects. Piping above or adjacent to switchboards should be avoided. Piping which must be located in the vicinity of a switchboard must be provided with suitable spray shields and have only welded joints.

12. Circuit Protection Devices.

a. Purpose. Overcurrent devices, the two most common types being fuse and circuit breakers, offer protection against currents in excess of the rated current of equipment or the current-carrying capacity (ampacity) of a conductor. The purpose of properly coordinated overcurrent protection is to recognize, locate, and isolate faulted portions of the power system in order to minimize the damage to equipment and conductors, danger to personnel, and interruption of electrical power which may result from an overload, short circuit, or ground fault.

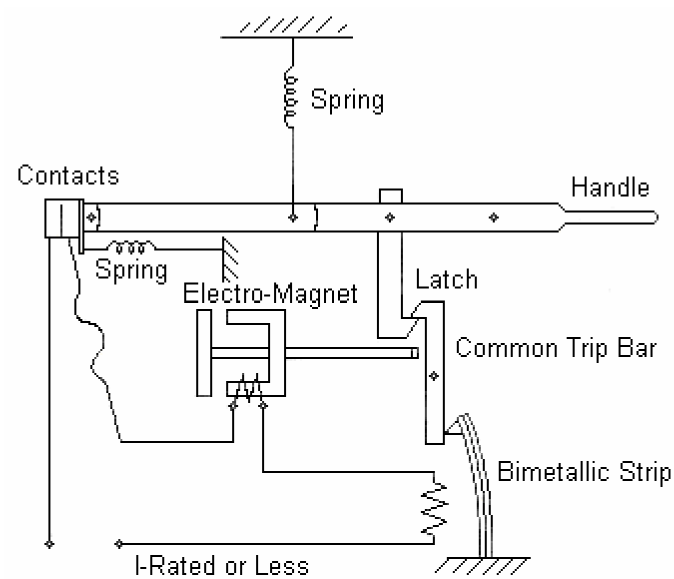
b. Circuit Breakers (46 CFR 111.54). Circuit breakers are devices which permit manual opening and closing of a circuit and which open the circuit automatically for a predetermined fault condition (usually overcurrent, but sometimes reverse power flow, under-voltage, or under-frequency) without damage to themselves when applied within their ratings. In effect, they are high current interrupting capacity switches with automatic trip elements. The circuit breakers most commonly found in marine applications respond to overcurrent, tripping when the current magnitude exceeds a specific value for a specific length of time. Low voltage (600 volts AC and below) circuit breakers are usually constructed with an integral overcurrent trip element within the circuit breaker housing.

In medium voltage systems, instrument transformers and protective relays separate from the circuit breakers are often used. Current transformers and voltage transformers are connected to the power system and allow the protective relays to "see" the conditions in the system without exposing them to the high system current and voltage levels. Protective relays interpret the information provided by the instrument transformers to discriminate between tolerable and fault/intolerable conditions. Upon detection of an intolerable condition, the protective relay initiates a tripping impulse to the circuit breaker, which isolates the faulted part of the power system.

When a circuit breaker opens an energized circuit, an arc is drawn between the opening contacts. This arc must be extinguished in order to interrupt the circuit. Circuit breakers are commonly classified according to the medium in which the contacts open. The common designations are air circuit breaker (which includes molded case circuit breakers), vacuum breakers, and SF6 (sulfur hexafluoride) breakers. Air circuit breakers are the most common type found in low voltage, relatively low current circuits for which the air around us serves as a suitable dielectric, preventing continued arcing between

3.G.12 b. (cont'd) the contacts after they have parted. Most air circuit breakers employ a bank of metal fins around the contacts to quickly extinguish arcs. As the arc passes between the fins it is split, cooled, and extinguished.

A molded-case circuit breaker is a type of air circuit breaker that is assembled as an integral unit in an insulated housing. Most molded-case breakers are provided with both a thermal trip for sustained overloads and a magnetic trip for instantaneous tripping on high fault currents. The operating mechanism that opens and closes the contacts includes a powerful spring that is charged when the breaker is closed. The trip actuator may have a number of inputs, but it must have a common mechanical output that releases the operating mechanism and uses the spring energy to open the contacts. Traditional circuit breakers have, for each pole a bimetallic thermal trip element and an electromagnetic (instantaneous) trip unit that initiate the mechanical motion of the trip bar which, in turn, releases the operating mechanism to open the contacts. Note that actuation of the common trip bar opens all the poles of the breaker simultaneously. This is illustrated in the figure below.



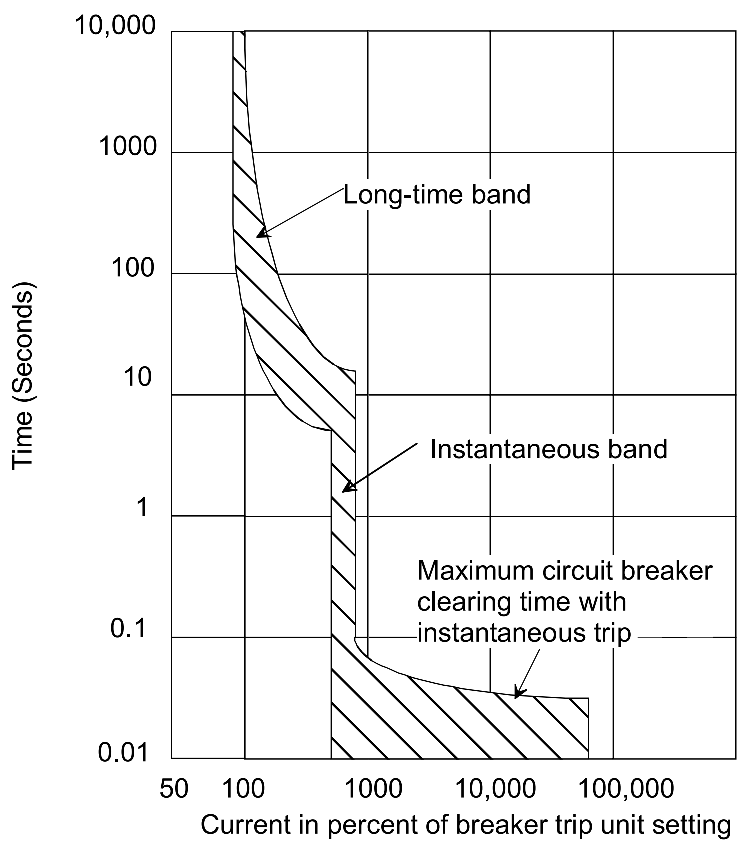
Electronic trip systems have been developed which replace the moving thermal-magnetic devices with solid-state electronic sensors and a single trip solenoid. By reducing the number of mechanical moving parts used to release the operating mechanism, electronic trip units can be made inherently more vibration and shock (impact) resistant. In addition, the electronic trip unit can be more closely adjusted and is less sensitive to ambient temperature because no motion of the trip actuator occurs until the trip signal is sent to the solenoid by the electronic circuit. With these advantages and the option for additional protection features, electronic trip units may soon replace thermal-magnetic elements for overcurrent protection.

The interrupting rating of a circuit breaker is the highest RMS (Root Mean Squared) current at rated voltage that the breaker is intended to interrupt in normal service. In practical circuits containing both resistance and reactance, most short-circuit currents will be

3.G.12 b. (cont'd) asymmetrical during the first few cycles after the short occurs. This asymmetry, due to a DC current component, will decay during the first few cycles until the current becomes symmetrical. The asymmetrical current, although it lasts only a short time, can greatly exceed the corresponding symmetrical fault current and the circuit breaker must be able to withstand the asymmetrical value. Under the ANSI standards presently applicable to low voltage fuses and circuit breakers, interrupting ratings are expressed in terms of the symmetrical RMS current to facilitate equipment comparison and selection. Circuit breakers meeting UL 489, although having only a symmetrical rating, are tested under conditions that evaluate their ability to withstand the "worst-case" asymmetrical current. It is not necessary to evaluate the device for asymmetrical current. Medium voltage circuit breakers have a first-cycle asymmetrical rating.

The continuous current rating of a circuit breaker is the continuous current the breaker will carry, without tripping, in the ambient temperature for which it is calibrated. Higher current will initiate tripping, though the current level must be sustained for some minimum length of time in order to actually trip the breaker. Circuit breakers trip on overcurrent according to a time-current response curve established by the manufacturer. A typical circuit breaker time-current characteristic curve is shown in the figure below.

Time-Current Response Curve



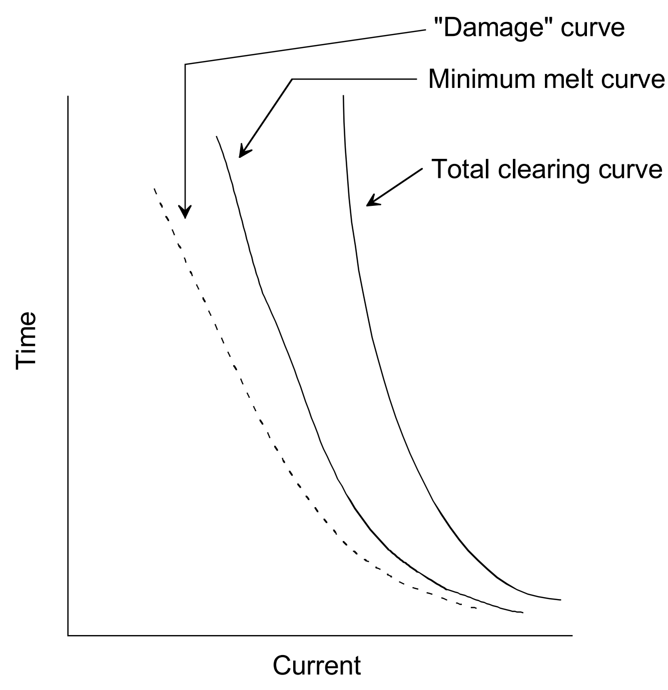
Circuit breakers that respond to overcurrent may have an inverse-time trip, an instantaneous trip, or both.

3.G.12 b. (cont'd) The term "instantaneous" here means only that no intentional time delay has been introduced, although some finite minimum time is required for any circuit breaker to interrupt a circuit. The curves indicate the length of time a particular current level must be sustained in order to trip a particular breaker. These and similar time-current curves for fuses are used in the process of coordinating the various overcurrent devices in the power system.

c. Fuses (46 CFR 111.53). Fuses are overcurrent protective devices containing a circuit-opening fusible element that is heated and severed by the passage of overcurrent. Fuses are among the few components required by the Electrical Engineering Regulations to be listed by an independent laboratory recognized by the Coast Guard (see 46 CFR 111.53-1(a)(3)). Fuses listed or labeled by a "nationally recognized testing laboratory" which has received recognition by OSHA are acceptable. Only "one-time" fuses may be used; renewable link cartridge-type fuses and Edison-base fuses (the screw-in type formerly used in residential fuse boxes) may not be used.

The interrupting rating (or capacity) refers to the highest RMS alternating current (or direct current depending upon the application), which the fuse is designed to interrupt without charring or cracking of the fuse tube or external arcing. The continuous current rating, or ampere rating, is the current level which the fuse will carry continuously without deterioration or excessive temperature rise. While fuses are often regarded as instantaneous circuit interrupting devices, they follow an extremely inverse time-circuit characteristic curve as shown below.

Fuse Characteristic Curve



The total clearing time curve shows the maximum time, including arcing time and manufacturing tolerances, for the fusible element to open the circuit. The minimum melt curve represents the minimum time

3.G.12 c. (cont'd) required for the fusible element to begin to melt. An assumed "fuse damage," curve, approximated at 75% of the minimum melting curve, is used to provide a margin of safety so that applications avoid operation in the time-current band between the minimum melt curve and the total clearing curve, where current levels may cause thermal damage to the fuse without opening the circuit.

Current-limiting fuses are used to limit the magnitude and duration of extremely high fault currents during the total clearing time. Current limiting becomes effective only above a specific threshold current and interrupts the circuit in less than one-half cycle after occurrence of a fault, before the fault current reaches its maximum magnitude. Current-limiting fuses can be used in combination with circuit breakers to provide protection of the circuit breaker against high fault currents while retaining the time delay thermal and instantaneous magnetic trips for overcurrents of lower magnitude. The heat energy developed in a circuit during the fuse's clearing time, expressed in ampere-squared-seconds as I2t, is used as one measure of a fuse's current-limiting ability.

d. Applications. Overcurrent devices are generally required to be located at the point of supply of the circuit to be protected. The Electrical Engineering Regulations contain specific exceptions for overcurrent protection for generators, shore power cables, and transformer secondary circuits. Most conductors must be provided with overcurrent protection to protect against thermal damage caused by current in excess of the ampacity rating of the conductor.

This level of overcurrent protection is not desirable in circuits that would affect vessel operation if unexpectedly opened. Only short-circuit (not overload) protection, set not less than 500% of the expected current, is allowed in electric propulsion control, voltage regulator, and circuit breaker tripping control supply circuits. Exceptions are also made for applications such as motor circuits where a higher trip rating may be necessary to avoid tripping on motor inrush currents. Similarly, the overcurrent protection requirements for transformers contained in Article 450 of the National Electrical Code reflect the need to avoid improper tripping due to magnetizing inrush currents while providing adequate protection against sustained overcurrent. Due to the vital role of the steering system in the overall safety of a vessel, only limited fault-current protection is permitted in steering gear motor feeder, motor controller, control, and indicating and alarm circuits. It would be dangerous to "protect" a steering-gear motor against a moderate overload if, by tripping the motor during a maneuvering situation, steering were lost and the safety of the vessel jeopardized. The fault-current protection required for steering systems is intended to protect against fire; components of the system may be sacrificed in order to maintain control of the vessel for as long as possible in emergency situations. Steering gear and propulsion circuits must meet 46 CFR 111.70.

13. Fault Current Analysis & Coordination (46 CFR 111.52).

a. Purpose. To provide for an electrical system that minimizes disruption from fault conditions, a fault current analysis and a coordination study must be performed. The fault current analysis is

3.G.13 a. (cont'd) used to determine the magnitude of available fault current throughout the system so that interrupting devices can be selected to safely open that magnitude of current. The coordination study is performed so that the overcurrent devices can be selected or set so that the device immediately upstream from the fault trips before devices further upstream, thereby limiting the power loss to equipment downstream of the fault.

Theory: The available short-circuit current at a given location in the power system is defined as the maximum current which the power system, when operating with the maximum generating capacity that can operate in parallel and the largest "probable" motor load, can deliver to a zero-impedance (bolted) three-phase fault. The sources of short-circuit current are the generators, synchronous motors or synchronous condensers, and induction motors in operation in the system. The connected (spinning) motors function as generators for a short time after a fault occurs, contributing current towards the fault. The subtransient reactance should be used to determine the contribution of induction motors to the fault current during the first few cycles after the occurrence of the fault.

The current that will flow toward the fault depends upon the power available from the source(s), the voltage at the fault (assumed to be zero for a bolted three-phase fault), and the impedance of the circuit components such as transformers, conductors, and other equipment between the fault and the power source(s). Short-circuit currents should be assumed to be asymmetrical during the first few cycles after the short occurs. The asymmetry will be maximum at the instant the short circuit occurs; in practical circuits containing both resistance and reactance, the current generally becomes symmetrical after several cycles. The rms value of the available asymmetrical current must be within the interrupting rating of the overcurrent device. Note that this maximum asymmetrical current is the average of the three phases at a particular instant in time and is not the maximum current in any one phase.

Low-voltage air circuit breakers operate nearly instantaneously for currents near their interrupting ratings. These breakers must be capable of interrupting the maximum current which can flow in the circuit However, since the interrupting ratings of low voltage circuit breakers are only expressed in terms of symmetrical rms amperes, only the symmetrical fault current needs to be determined. The breaker frame size should be selected to have a (symmetrical) interrupting rating at least equal to the calculated symmetrical short-circuit current.

Calculation Procedures: There are a number of methods, of various degrees of accuracy and simplicity, which can be used to determine the available fault current. The Electrical Engineering Regulations permit the use of the assumptions contained in 46 CFR 111.52-3 in lieu of detailed short-circuit calculations for systems with an aggregate generating capacity below 1500 kilowatts.

This refers to the condition where the maximum number of generators which can operate in parallel are operating, generating the maximum power which can be supplied to the system. Detailed calculations may utilize any of the following methods:

3.G.13.a (1) Exact calculations using actual impedances and reactance's of the electrical equipment in the system.

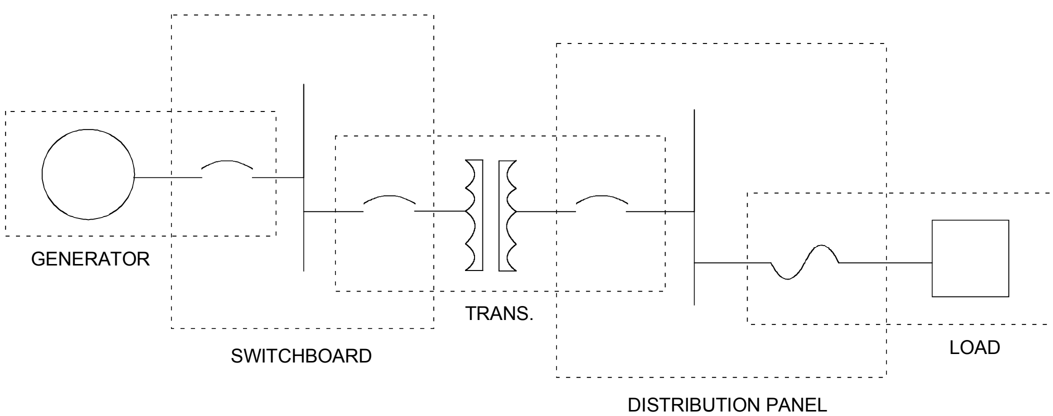
(2) Estimated calculations using the Naval Sea Systems Command Design Data Sheet DDS 9620-3, "A.C. Fault Current Calculations."

(3) Estimated calculations using the International Electrotechnical Commission (IEC) Publication 363 (1972), "Short-circuit Current Evaluation with Special Regard to Rated Short-Circuit Capacity of Circuit Breakers in Installations in Ships."

(4) Estimated calculations using an established, commercially available fault current analysis procedure for utility or industrial applications, provided sufficient documentation regarding the procedure is submitted to verify its applicability. The estimated calculation procedure often contain certain "simplifying assumptions" regarding the reactance-to-resistance (X/R) ratios for generators, motors, and transformers, as well as the power factor and efficiency of induction motors. Low voltage systems are generally assumed to experience no voltage drop throughout the system. The maximum fault current is normally calculated at the first half-cycle. Simplifying assumptions may be used, consistent with good engineering judgment. The use of such assumptions must be noted in the calculations.

b. Coordination. Coordination, sometimes called selectivity, refers to the location of overcurrent protective devices in the system and the selection of proper trip ratings or settings and coordination time intervals so that only the smallest practicable portion of the power system will be isolated following a fault. The protection system can be viewed as a set of overlapping zones of protection with each zone encompassing a segment of the power system including at least one circuit breaker or fuse, as shown in the figure below.

Protection System Zones



In a properly coordinated radial system, the first circuit interrupting device on the source side of the fault should respond (by opening the circuit) the fastest, so that no other interrupting devices open and maximum continuity of power is provided to the remainder of the system. Each circuit-interrupting device should

3.G.13 b. (cont'd) provide backup protection for the interrupting devices downstream of it; that is, each interrupting device should be able to open the circuit for any fault that the next downstream device fails to clear, but only after allowing sufficient time for the downstream device to act. The coordination time interval is the time difference between the slowest operating time for the primary protection and the fastest time for the backup protection.

Proper coordination of protective devices requires an analysis of the fault currents available at the various points in the system, selection of the circuit breakers and fuses so that each will clear the anticipated fault currents in an acceptable time, and verification that each breaker or fuse provides adequate backup protection for the circuit interrupters downstream. In general, "instantaneous" or extremely inverse characteristic circuit breakers, or fuses, are used at loads (the farthest downstream devices) with progressively less inverse time-current characteristic breakers employed as one approaches the source(s). An exception is the requirement of 111.12-11(c)(2) for an instantaneous trip on the generator circuit breaker where three or more generators can be paralleled.

Coordination of molded case circuit breakers having thermal magnetic trips is sometimes difficult. In view of this, non-selective overcurrent protection may be accepted for circuits that supply only non-vital equipment. A fault on such circuits must not affect the continuity of electric power to equipment vital to the propulsion, control, or safety of the vessel.

14. Wire and Cable (46 CFR 111.60).

a. General. A wire is a conductor with functional insulation only, for use inside an enclosure. A cable consists of one or more insulated conductors provided with a protective covering of either a watertight metallic sheath or an impervious non-metallic sheath compatible with the insulation. Most shipboard wiring is accomplished using multiconductor cable.

Wire and conduit may be used for shipboard wiring. Where it is used, the installation requirements of the NEC should be followed (i.e., requirements for sizes and fill, bends and bending methods, couplings and connectors, and support methods and locations), and the additional aspects of a marine installation (corrosion, moisture, watertight bulkhead penetrations, and flexing) should be addressed. Additionally, the wire must meet the requirements of 46 CFR Subpart 111.60 for insulated conductors.

The design emphasis for merchant vessel cable has historically been placed on the harsh ship construction environment (nearby welding, pulling cable through bulkheads, and subjecting cable to constant mechanical abuse), as well as on the shipboard operating environment (clamped assemblies, large cable bundles, and exposure to a wide range of temperatures, high humidity, and oil). Additional considerations for vessels have included longitudinal water propagation resistance, overload conditions, and circuit integrity under fire conditions.

3.G.14 b. Types of Cable. The regulations for the construction of shipboard electrical cable are contained in 46 CFR 111.60. A current copy of the regulations should be referenced as types of acceptable cable may be changing.

For cables listed by UL for 90°C, use the (E,X) column ampacities. If UL listed for 75°C, use the (T) column ampacities. These ampacities should be used regardless of the actual insulation composition of the cables. The ampacities of cables having a UL shipboard listing may be found in Table 9.1, of IEEE-45 (1998 edition).

All UL cable listings for shipboard applications must be for a maximum conductor temperature of 100°C or less. The 100°C limitation does not apply to DC cable utilized in MODU industrial systems. As an alternative to the cable construction and sizing requirements of 46 CFR 111.60, DC cables on MODUs may meet the requirements of the International Association of Drilling Contractors (IADC) Standard DCCS-l, "Interim Guidelines for Industrial System DC Cable for Mobile Offshore Drilling Units". In accordance with this standard, marine cables may be listed by UL for up to 110°C. The current-carrying capacity of 110°C rated cables is 1.14 times the 90°C (E,X) rating column in IEEE-45. If the UL listing is for 100°C or less, however, the cable cannot be used at the 110°C rating. Industrial system cable rated and utilized (sized) at 110°C may be run with other cables, without maintained spacing (i.e., banked) if derated in accordance with Note 6 of Table 9.1 of IEEE-45.

It should be noted that some types of cable constructed in accordance with MIL-C-915 are not required to meet the flame propagation requirements of IEC 60332-3-22 or IEEE Standard 1202. Therefore, it may be necessary to verify that a MIL-C-915 cable type meets the flammability test of IEC 60332-3-22 or IEEE Standard 1202.

The Naval Sea Systems Command (NAVSEA) publishes two military specifications on the construction of shipboard electrical cable. The first specification, MIL-C-24640 (Cable, Electrical, Lightweight, for Shipboard Use), addresses lightweight power, lighting, and communication cable with a crosslinked polyolefin jacket. The second, MIL-C-24643 (Cable and Cord, Electrical, Low Smoke, for Shipboard Use), addresses electrical cable which exhibits low smoke generation characteristics when subjected to specific smoke and flame tests. The ampacities for these Navy cables may be found in "Cable Comparison Handbook, HDBK-299, issued 3 April 1989." Although this handbook addresses standard Navy cable size designations, it should also be used for the AWC sized cables of MIL-C-24640 having similar (not necessarily identical) cross-sectional areas. Industry needs have led to modifications to acceptable cable construction on vessels. In most cases, these modifications are superior to the minimum requirements and should be permitted. Although NEC Article 310-3 permits solid conductors for size No. 10 AWG and smaller, solid conductors are unacceptable for shipboard power cables. Nicks on solid conductors from insulation removal are likely to lead to conductor breakage with shipboard vibration. Electrical Engineering Regulations require shipboard cable to meet the flammability requirements of the standard the cable was constructed to.

3.G.14 b. (cont'd) Shipboard cable flammability was addressed internationally in IMCO Resolution A.325 (IX), which was adopted on November 12, 1975. Paragraph (e)(ii) of Regulation 23 of that Resolution requires that all electric cables be at least of a flame retardant type and installed in a manner that does not impair their original flame retarding properties. This requirement is found in 2001 Amendments to SOLAS 1974 / II-2 Regulation 45.5.2. Attempting to provide guidance on how to meet the SOLAS Amendments, IEC Technical Committee 18 developed guidelines which stated that cables should either be qualified using a flame propagation test procedure for bunched cables or that special precautions be taken. These special precautions can be achieved by the use of fire barriers as follows:

(1) Fire stops having at least B-O penetrations are to be fitted:
   (a) At cable entries at the main and emergency switchboard,
   (b) Where cables enter engine control rooms,
   (c) At cable entries at centralized control panels for propulsion machinery and essential auxiliaries,
   (d) At each end of totally enclosed cable trunks.

(2) In enclosed and semi-enclosed spaces, cable runs are to:
   (a) have either a fire protection coating applied:
      i. to at least 1 meter in every 14 meters for horizontal runs; and,
      ii. to the entire length of vertical runs; or,
   (b) be fitted with fire stops having at least B-O penetrations every second deck or approximately 6 meters for vertical runs and at every 14 meters for horizontal runs.

The cable penetrations are to be installed in steel pipes of at least 3 mm thickness extending all around to twice the largest dimension of the cable run for vertical runs and once for horizontal runs, but need not extend through ceilings, decks, bulkheads or solid sides of trunks. In cargo areas, fire stops need only be fitted at the boundaries of the spaces.

In 2000, IEC developed a new series of tests on electric cables under fire conditions- test for vertical flame spread of vertically mounted bunched wires or cables. IEC 332 part 3 has been replaced by IEC 60332-3-22 Cat A which is the acceptable test for all cable constructed to IEC 60092-353.

In addition to the standards referenced in 46 CFR 111.60-1, cable constructed in accordance with one of the following can be accepted:
(1) Cable having a UL shipboard cable listing;
(2) For DC industrial systems on MODUs, cable meeting the requirements of IADC Standard DCCS-l;
(3) Cable constructed in general accordance with an above standard but modified in a manner clearly superior to the minimum requirements specified. Examples of such modifications have been discussed above.

c. <u>Unique Application</u>. Special purpose cables may be used for unique applications where there is a compelling reason for deviating from the cable construction standards discussed above in order to satisfy system requirements. Such special purpose cables may include coaxial, triaxial, and low noise signal cables. Exceptions to the construction

3.G.14 c. (cont'd) and testing requirements for such cables exist in both Section 9.1 of IEEE-45 and SOLAS II-1/45.5.2. The primary concern with these cables is flame propagation. If a particular cable type cannot be shown to comply with the IEEE-1202 or IEC 60332-3-22 (Cat A) fire tests, then the special precautions discussed earlier should be used to achieve a flame propagation resistant installation. If special purpose cables are run singly (not in or near bundles or cable trays with other cables), then self-extinguishing construction is acceptable.

As discussed in Section 7 of this guide, cables in intrinsically safe circuits need not meet the cable construction requirements of 46 CFR 111.60. These cables must have sufficient dielectric strength for the maximum voltage in the circuit, and must be of self-extinguishing construction and run singly, comply with the IEEE-1202 or IEC 60332-3-22 (Cat. A) fire tests, or be installed using the special precautions to achieve a flame propagation resistant installation.

Fiber optic cable is addressed in 46 CFR 111.60-6. Since fiber optic cables present no shock or ignition hazards, concern is limited to the flame propagation issue. Fiber optic cables must meet the flammability test of the standards listed in 46 CFR 111.60-6(a) or be installed in accordance with the special installation precautions discussed earlier.

d. Ampacity. The ampacity of a cable is the maximum current-carrying capacity of the cable, based on the cross-sectional area of the conductors, maximum allowable conductor temperature for the insulation used, and the ambient temperature. The temperature rating of a conductor is the maximum temperature, anywhere along its length, that the conductor can withstand for a prolonged period without serious degradation of its insulation. Conductors with a temperature rating above the maximum ambient temperature must be used. Tabulated ampacities should be corrected for the anticipated ambient temperature and method of cable installation (banking of cables) using the ampacity correction factors applicable to that table. Adjacent or closely spaced cables both raise the ambient temperature and impede heat dissipation. It is important to read the notes for each table to know the ambient temperature and method of cable installation upon which the tabulated ampacities are based, so that the proper correction factors may be applied.

The existing cable application guidance in 46 CFR 111.60-3 uses some old standard editions, for example the 1983 edition of IEEE Std 45. Newer standard editions are under consideration for incorporation. During the interim, the following may be used on an equivalency basis with the standards listed in 46 CFR 111.60-3: Cable constructed according to IEEE Std 1580 (2001) that meets the provisions for cable application of section 24 of IEEE Std 45 (2002), and is derated in accordance with Table 25, Note 6, of the same standard. Cable for special applications defined in section 24 of IEEE Std 45 (2002) that meets the provisions of that section. Cable constructed according to IEC 60092-353 (1995) or UL 1309 (1995) that meets section 24 of IEEE Std 45 (2002), except 24.6.1, 24.6.7, and 24.8. Cable constructed according to IEC 60092-353 (1995) may meet IEC 60092-352 (1997), Table 1, for ampacity values, and be derated according to IEC

3.G.14 d. (cont'd) 60092-352 (1997), paragraph 8. UL 1309 (1995) cable ampacities are contained in the appendix of that standard.

The ampacity of a four-conductor cable, where one conductor is the neutral which carries only the unbalanced current (normally small) from the other conductors, is the same as that of a three-conductor cable. Where four or more current-carrying power conductors are used in a cable, as in a MODU topdrive system, the maximum current carrying capacity of each conductor must be reduced in accordance with the number of power conductors in a cable (not in a tray).

e. Minimum Conductor Size. The Electrical Engineering Regulations specify minimum cable conductor sizes of 22 AWG for thermocouple and pyrometer cables, 14 AWG for lighting and power cables, and 18 AWG for other cable conductors. The regulations also require each wire to be at least 18 AWG, and wires in switchboards to be at least 14 AWG. These minimum sizes are considerably larger than the conductors commonly found in ribbon cables, used to interconnect printed circuit boards and computer system components.

Where ribbon cables or similar small conductor size cables are recommended for use in low-power instrumentation, monitoring, and control circuits by the equipment manufacturer(s), the use of such cables may be permitted. Additional mechanical protection may be required to protect the conductors from parting due to mechanical damage or flexing. Ribbon cables are usually found within equipment or consoles. However, they are sometimes used externally to interconnect modules. The location of the cable aboard the vessel and the function of the circuit will determine the extent of mechanical protection required, if any.

The requirement for 14 AWG minimum wire in switchboards was written with full voltage, field-wired switchboard equipment in mind. Wire smaller than 14 AWG may be considered for low voltage, low-power circuits within switchboards.

f. Fiber Optic Cables Cord. Each fiber optic cable must be constructed to pass IEEE Std 1202 or IEC 600332-3-22 (Category A) flammability test. Fiber optic cable must be installed in accordance with 46 CFR 111.60-2.

g. Flexible Cord. Flexible electric cords and cables may be used only as allowed by Table 400-4 and Sections 400-7 and 400-8 of the NEC, per 46 CFR 111.60-13. They must not be used for fixed wiring, unless they are dual rated as either flexible cable or cord and shipboard cable listed by UL. No. 18 AWG conductors are permitted in power and lighting circuits only for portable applications.

h. Color Coding. The Electrical Engineering Regulations do not require the use of any particular conductor color coding scheme. The only requirement is that an insulated equipment grounding conductor in a cable must have green braid or insulation, per 46 CFR 111.05-33(b). Different color codes for circuit conductors may be found in the incorporated cable construction standards and NEC Sections 210-5 and 310.12. Although the regulations do not require the use of a specific color scheme for the ungrounded conductors of a circuit, it is recommended that some consistent coloring or marking practice be used

3.G.14 h. (cont'd) for multiwire circuits in order to provide positive identification of circuit conductors and facilitate troubleshooting and repair.

i. Cable Installation. Each cable installation must meet the general requirements of the standard to which they were constructed. The use of nylon or plastic cable straps is explicitly recognized for horizontal runs where the cable will not fall if the strap fails. They are permitted where the cable strap is used to maintain spacing and not for support of the cables. IEEE Standard 45 requires metallic band strapping to be a minimum of 5/8 inch wide. Deviations from this dimension may be permitted where the width of the strap provides sufficient mechanical strength to support the cables and does not cause chafing of the cable jacket when the strap is tightened.

Twist-on wire connectors, or "wire nuts," (TM) are pressure-type connectors which may be used per 46 CFR 111.60-17. Connections using twist-on connectors must be made within an enclosure. The use of insulating electrical tape over connectors is recommended. Twist-on connectors are not recommended for use on small vessels due to the pounding motions frequently encountered. Additionally, they are not recommended for use in vital circuits, such as those powered from the emergency switchboard. Pressure connectors are typically designed for non-marine-stranded conductors. This may present a problem, especially with smaller conductors. Some twist-on connectors have sharp metallic inserts that could sever individual wires as they cut their way into the copper. Installations must be carefully examined to ensure that connections are tight, and that conductors have not been damaged.

When pressure type connectors are used, the proper size is important. The connection must be tight, yet it must not be necessary to remove strands to fit the connector body to the conductor. This can sometimes present problems since marine cable has a different conductor diameter than NEC constructions.

Methods of connection of conductors to terminal parts, other than those listed in 46 CFR 111.60-17, may be accepted provided they insure a sound mechanical and electrical connection without damaging the conductors. A twisted, soldered loop may be used to connect a stranded conductor to a terminal screw on receptacles and lampholders where supplied by a circuit having a grounded conductor, a lampholder of the screw-shell type should have the grounded conductor connected to the screw-shell.

Requirements for cable splicing are contained in 46 CFR 111.60-19, which references section 20.11 of IEEE Std. 45. Splicing may be used to connect cables in one subassembly to cables in another subassembly, or to facilitate modular construction techniques. Splicing is also acceptable during alterations to extend a circuit, or to facilitate installation of an exceptionally long cable. Sections of replacement cable may be spliced in to replace damaged areas if the remainder of the cable is proven to be safe. A cable may not be spliced in a hazardous area, except in intrinsically safe systems.

3.G.14 i. (cont'd) The safety and reliability of a spliced cable is dependent upon the careful selection of the proper connectors, insulation and jacket replacement material, installation tools, and installation procedures. It is most important that the right size connector be used for the cable, with no trimming of the conductors. Selection of the proper connector for the conductor, the proper compression die for the connector, and the proper compression tool for the die is critical to the mechanical and electrical integrity of the splice. The type of crimp is not really important, as long as it does not leave sharp edges that may damage insulation. Manufacturer's certification of material compatibility is generally acceptable. The replacement insulation material need not match the cable jacket material as long as the temperature characteristics and materials are compatible.

Heat shrinkable or pre-stretched tubing is acceptable, as well as poured epoxy, polyurethane, and vulcanized replacement jackets. Flame propagation is not a major concern for the short lengths of cable splices. While splices made in the open are prohibited in hazardous locations, cables may be connected in hazardous locations in junction boxes (explosion proof in Division 1 and Zone 0). Note that flexible cables or cords with conductors of 12 AWG or larger may be spliced for repairs, per 46 CFR 111.60-13(e).

(j) Cable Armor. 46 CFR 111.105-17 recommends the use of armored cable to enhance ground detection capabilities. Another purpose of the recommendation for armor is to give added mechanical protection to avoid possible arcing from an accidentally severed cable as well as enable quicker detection, via the ground detection system, of damaged cable insulation. With intrinsically safe systems used in hazardous locations, the armor is unnecessary for this purpose since the energy available in the system is insufficient to constitute an ignition hazard. However, if there is insufficient cable separation, or there is no grounded partition, then a metal weave or shield around the cable is required to prevent the possible induction of current within the intrinsically safe circuit. This metallic covering may be inside an outer cable jacket. See 111.105-11(b) on the use of shielded cables.

An exception to the recommendation for armored cable in hazardous locations is when flexible cord or cable must be used to connect electrical equipment. This flexible cable need not be joined to armored cable immediately beyond the section that requires flexing service. Rather than make such a connection in an explosionproof junction box within the hazardous location, it is generally preferable to extend the flexible cable to its point of supply outside the hazardous area. However if a run of flexible cable is particularly vulnerable to mechanical damage, connection to armored cable or some other means of mechanical protection may be required.

3.G.14 j. (cont'd) Where single-conductor cables are used for AC circuits or DC circuits with high ripple content, the following precautions should be observed in order to avoid undesirable induced currents and generated heat:

(1) Cable armor, if any, should be of non-magnetic material;
(2) There should be no closed magnetic circuit around any conductor unless it encircles all conductors of the circuit; where installed in steel conduits, pipes, or casings, the cables should be bunched so that all conductors and the neutral, if any, are enclosed by the same conduit, pipe, or casing;
(3) No magnetic material should be located between single-conductor cables of a circuit; where such cables pass through a steel deck or bulkhead, all the conductors of the circuit should pass through a non-ferrous plate or gland so that no magnetic material is located between the conductors.

Cable routing and segregation requirements are contained in 46 CFR 111.60-9 and 111.60-5, which references IEEE-45 Sections 20 and 22, except 20.11. Section 20.3 requires cables to be so routed as to avoid, so far as practicable, galleys, firerooms, and other spaces where excessive heat and high risk of fire may be encountered. SOLAS II-1/45.5.3 includes laundries in this category of spaces to be avoided.

15. Motor Circuits (46.CFR 111.70).

a. General (46 CFR 111.70-1). With the exception of steering gear motor circuits, propulsion motor circuits (which must meet 46 CFR Subparts 111.70 and 111.35, respectively) and certain special requirements applicable to fire pump motor circuits, each other motor circuit, controller, and protection must meet the requirements of ABS Rules for Building and Classing Steel Vessels (RSV Rules) or ABS Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules), as applicable. 46 CFR 111.70-1 currently references sections 4/5A5.13, 4/5B2.13, 4/5B2.15 and 4/5C4 of the 1996 RSV Rules; these correspond to sections 4-8-2/9.17, 4-8-3/5, and 4-8-4/9.5 of the 2003 RSV rules. Sections 4/3.87 through 4/3.94 and 4/3.115.6 of the 1994 MODU Rules correspond to Part 4, Chapter 3, sections 4/7.11 and 4/7.17 of the 2001 MODU Rules. Previously 46 CFR 111.70 relied on Article 430 of ANSI/NFPA 70, the National Electrical Code (NEC). In 1996 subpart 111.70 was revised to reflect internationally recognized classification society standards, practices and requirements which do not rely solely on the shoreside code of the National Electrical Code (NEC). Referencing section 430 of the NEC may still be useful as indicated in the following sections, but is no longer binding.

Diagram 430-1 in the NEC is a useful diagram of a motor circuit. The diagram serves as a guide to the applicability of the various sections of Article 430; the NEC does not require all motor circuits to be arranged as shown in the diagram. In fact, the vast majority of shipboard low-voltage motor circuits consist of the motor, a combination motor controller containing overload protection which meets NEC 430 Part C and a disconnecting means which meets 430 Part H, fuses or a circuit breaker which provide branch-circuit short-circuit and ground-fault protection per 430 Part D, and motor branch-circuit conductors meeting 430 Part B.

3.G.15 b. 600 Volts and Above. Part K of NEC Article 430 adds to or amends the other provisions of the article for motor circuits over 600 volts. Specifically, 430-124 permits motor conductors to have an ampacity not less than the motor overload protective device trip current, which may be 100% of the rated full-load current. This applies to medium-voltage motors for applications such as thrusters and compressors. Cables for DC motors for drilling equipment (draw-works, rotary table, mud and cement pumps) may be sized in accordance with the International Association of Drilling Contractors "Interim Guidelines for Industrial System DC Cable for Mobile Offshore Drilling Units," IADC-DCCS-l. This standard is under section 3.G.15.d.

c. Motor Protection. Motor overload protective devices are required for most motors in order to protect the motors, motor control equipment, and motor branch-circuit conductors against excessive heating due to sustained motor overload, failure to start, or motor stalling. Continuous-duty motors of more than 1 horsepower must generally be provided with a separate overload device set to trip at not more than 115% of the motor rated full-load current. In most cases, overload relays with heater coils responsive to the motor current are included in the motor controller. The Electrical Engineering Regulations generally permit the use of only two motor overload devices for three-phase motors in lieu of the three specified in NEC Table 430-37; see 46 CFR 111.70-1(b). The size of the overload protective device should be based upon the actual nameplate full-load current rating. The values listed in columns "C" and "D" of the Quick Reference tables in section 3.G.15.e may be used to check the maximum values for running protection.

Part D of Article 430 specifies the protection of motor circuits rated 600 volts or less against overcurrent due to short circuits or grounds. A single protective device may be used to provide both branch circuit/ground-fault and motor overload protection where the overload requirements of 430-32 are met; see NEC 430-55. NEC 430-52 permits a motor short-circuit protector (MCP) to be used in lieu of the protection specified in Table 430-152 where the motor short-circuit protector is a part of a combination controller which has both motor overload protection and short-circuit and ground~fault protection in each conductor and where it will operate at not more than 1300 percent of motor full-load current.

Motor controllers, also called "starters," are used to manually or automatically start electric motors from a local or remote location. Motor controllers basically consist of a relay or "contactor," which is used to connect the motor to the AC line by a pushbutton switch, liquid level switch, pressure switch, temperature switch, etc. The two types of controllers used are "low voltage release" (LVR) and "low voltage protection" (LVP). Both can appear to be identical, but their electrical circuits will vary. LVR controllers are required for vital systems to ensure that the equipment will re-start following either a loss of power or a reduction in voltage below the "drop-out" value of the operating coil. These controllers are usually energized by contacts that mechanically remain closed when power is lost. LVP controllers are energized by momentary contacts, such as a

3.G.15 c. (cont'd) pushbutton. They will not re-start following a power outage until the momentary pushbutton contact is again depressed.

Motor controllers are furnished with the thermal overload elements mentioned above. These elements are used to open (or close) contacts which are used either in the control circuit itself or to provide an overload alarm to another circuit.

Some of these elements are adjustable but most often the non-adjustable type is specified. Most motors are stopped by these (normally closed) contacts when an overload occurs. For vital systems, such as steering, these devices are used only to signal the overload condition in a separate circuit.

Safety disconnects: Each motor circuit must have a disconnecting means capable of disconnecting both the motor and the controller from the circuit. The disconnect and the controller may be contained within the same enclosure; the disconnect must, however, open all ungrounded supply conductors to the controller and motor control circuits. Switches and circuit breakers used as disconnecting means for low-voltage motor circuit must have ampere rating of at least 115 percent of the motor full-load current. The use of fuses as disconnects, although permitted by the NEC, is specifically prohibited by 46 CFR 111.70-1(c). Electric heaters in motor controller enclosures should not be accepted from the disconnecting requirements in 46 CFR 111.70-5(a). The purpose of this requirement is to eliminate the shock hazard posed to personnel by an enclosure with more than one source of potential, and is consistent with the intent of NEC 430-113. To allow for safe access during maintenance and inspection shutdown periods, a disconnecting device for an electric heater in a motor controller enclosure, or one of the protection features required by 111.70-7(d) for control, interlock or indicator circuits should be provided.

d. Interim Guidelines For MODUs. Reference 3.G.15.b

INTERNATIONAL ASSOCIATION DRILLING CONTRACTORS

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INTERIM GUIDELINES
FOR INDUSTRIAL SYSTEM DC CABLE
FOR MOBILE OFFSHORE DRILLING UNITS
IADC-DCCS-1

I. Purpose

These interim guidelines have been prepared to establish a method for the selection, installation and acceptance of DC electrical cables used on industrial drilling systems on mobile offshore drilling units. These systems are drawworks, pumps and rotary table. These interim guidelines will provide the necessary

3.G.15 d. (cont'd) guidelines for DC cable on MODUs until a final standard has been prepared and issued.

II. Single Conductor Cable Selection

For all cable types, the following shall apply:

A. The interim guidelines shall apply to DC motors nominally rated 750 volts DC armature voltage.

B. The cable size per polarity shall have a current-carrying capacity determined by multiplying the duty factor times the lesser of:

1. The continuous current rating of the motor; or
2. The continuous current limit setting of the power supply.

C. The duty factors to be used are:

1. Mud pumps, cement pumps: 0.80;

2. Drawworks, rotary: 0.65.

D. The cable need only be sized for a maximum ambient temperature of 45 C in machinery spaces as determined by the U.S. Coast Guard, the American Bureau of Shipping and the Marine Transportation Committee of the Institute of Electrical and Electronic Engineers.

E. The cable shall meet the flame retardancy requirements of IEEE-383-1974 or IEEE-45-1977. Manufacturer shall supply to the owner of the vessel a certificate of compliance with this requirement.

F. The voltage rating of the cable shall be 1000 volts minimum.

G. For this specification, the cable insulation and jacket shall meet or exceed the requirements of the latest edition of one or more of the following standards as it applies to the construction of a single conductor power cable. Where the following standards do not specifically list AAR-sized cable, the insulation and jacket thickness shall conform to the next larger size cable listed.

1. Rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-19-81);

2. Cross-linked Thermosetting Polyethylene-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-66-524);

3. Ethylene-Propylene Rubber-insulation Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-68-516);

4. Specification for Single Conductor Cleaning-stripping Ethylene-Propylene Rubber-insulated 0-600 Volt (see A and E of this interim guideline) Chlorosulfonated Polyethylene-jacketed Cable for Locomotive and Care Equipment (AAR Specification 591). NOTE: The insulation and jacket thickness of AAR 591 are suitable for 1000 volts based on comparison with ICEA S-68-516 for 0-2000 volt rating.

3.G.15 d. (cont'd) The manufacturer shall test, certify and label the cable with appropriate voltage ratings.

5. American Association of Railroads (AAR) Wiring and Cable Specifications S-501.

6. IEEE Recommended Practice for Electrical Installations on Switchboards (IEEE-45).

7. General Specifications for Cable and Cord Electrical for Shipboard Use (Military Specification MIL-C-915E).

8. Any UL-listed Marine Shipboard Cable

e. Motor Circuit Information.

Figure 1, reference 3.G.15.c

3-Phase, 208 VAC Motor Branch Circuit Quick-Reference Table for Single Banked Cables									
A	B	C	D	E	F	G	H	I	J
HP	FLA	Running Prot. 115% FLA.		Starter Size	Disconnect Size	Max. Prot. Device Full Volt Start			
		Adj.	Non-Adj.			Code C.B. 200%	B-E Fuse 250%	Code C.B. 250%	F-V Fuse 300%
.25	1.23	1.41	2	00	30	15	15	15	15
.33	1.48	1.7	2	00	30	15	15	15	15
.5	2.0	2.3	3	00	30	15	15	15	15
.75	2.8	3.22	4	00	30	15	15	15	15
1	3.6	4.14	4	00	30	15	15	15	15
1.5	5.7	6.56	8	00	30	15	15	15	20
2	7.8	8.97	10	0	30	20	20	20	25
3	10	11.5	12	0	30	20	30	30	30
5	17	19.6	20	1	60	35	40	50	60
7.5	24	27.6	30	1	60/100	50	50	70	80
10	31	35.7	40	2	100	70	70	90	100
15	46	52.9	60	3	100/200	100	100	125	150
20	59	67.9	70	3	200	125	125	150	200
25	75	86.3	100	3	200/400	175	175	200	250
30	88	101	110	3	200/400	200	200	125	300
40	114	131	150	4	400	250	250	300	350
50	143	164	200	4	400/600	300	300	400	450
60	170	196	225	5	400/600	350	350	500	500
75	212	243	250	5	600	500	500	600	-
100	273	314	350	5	600	600	600	-	-
125	343	394	450	6	-	-	-	-	-
150	396	455	500	6	-	-	-	-	-
200	528	607	800	6	-	-	-	-	-

Figure 1, reference 3.G.15.c (cont'd)

3-Phase, 208 VAC Motor Branch Circuit Quick-Reference Table for Single Banked Cables (cont'd)						
	K	L	M	N	O	P
HP	125%	Three Conductor Branch Cable				
		AWG (IEEE 45, 50 C)			TSGA – ( )	
		T	E, X	AVS	40 C	50 C
.25	1.54	14	14	14	4	4
.33	1.85	14	14	14	4	4
.5	2.51	14	14	14	4	4
.75	3.5	14	14	14	4	4
1	4.5	14	14	14	4	4
1.5	7.13	14	14	14	4	4
2	9.75	14	14	14	4	4
3	12.5	14	14	14	4	4
5	21.3	12	14	14	9	9
7.5	30.0	10	10	12	9	9
10	38.8	7	8	10	9	14
15	57.5	5	6	7	23	23
20	73.8	3	4	5	30	30
25	93.8	1	2	3	40	50
30	110.0	1/0	1	2	50	60
40	142.5	3/0	2/0	1/0	75	100
50	178.8	4/0	3/0	2/0	125	125
60	212.5	300	250	4/0	150	150
75	265.0	400	350	250	200	250
100	341.3	600	500	400	300	400
125	428.8	-	-	-	400	-
150	495.0	-	-	-	-	-
200	660.0	-	-	-	-	-

Figure 2, reference 3.G.15.c

3-Phase, 460 VAC Motor Branch Circuit Quick-Reference Table for Single Banked Cables									
A	B	C	D	E	F	G	H	I	J
HP	FLA	Running Prot. 115% FLA.		Starter Size	Disconnect Size	Max. Prot. Device Full Volt Start			
		Adj.	Non-Adj.			Code C.B. 200%	B-E Fuse 250%	Code C.B. 250%	F-V Fuse 300%
.5	1	1.15	2	00	30	15	15	15	15
.75	1.4	1.61	2	00	30	15	15	15	15
1	1.8	2.07	3	00	30	15	15	15	15
1.5	2.6	2.99	3	00	30	15	15	15	15
2	3.4	3.91	4	00	30	15	15	15	15
3	4.8	5.52	6	0	30	15	15	15	15
5	7.6	8.74	10	0	30	20	20	20	25
7.5	11	12.65	15	1	30/60	25	30	30	35
10	14	16.1	20	1	30/60	30	35	35	45
15	21	24.15	25	2	60/100	45	60	60	70
20	27	31.05	35	2	60/100	60	70	70	90
25	34	39.1	40	2	100/200	70	90	90	110
30	40	46	50	3	100/200	90	100	100	125
40	52	59	60	3	200	125	150	150	175
50	65	74.75	80	3	200	150	175	175	200
60	77	88.55	90	4	200/400	175	200	200	250
75	96	110.4	125	4	400	200	250	250	300
100	124	142.6	150	4	400	250	350	3350	400
125	156	179.4	200	5	400/600	350	400	400	500
150	180	207	225	5	600	400	450	450	600
200	240	276	300	5	600	500	600	600	-

Figure 2, reference 3.G.15.c (cont'd)

3-Phase, 460 VAC Motor Branch Circuit Quick-Reference Table for Single Banked Cables (cont'd)						
	K	L	M	N	O	P
HP	125%	Three Conductor Branch Cable				
		AWG (IEEE 45, 50 C)			TSGA – ( )	
		T	E, X	AVS	40 C	50 C
.5	1.25	14	14	14	4	4
.75	1.75	14	14	14	4	4
1	2.25	14	14	14	4	4
1.5	3.25	14	14	14	4	4
2	4.25	14	14	14	4	4
3	6	14	14	14	4	4
5	9.5	14	14	14	4	4
7.5	13.75	14	14	14	4	4
10	17.5	14	14	14	4	9
15	26.25	10	10	12	9	9
20	33.75	8	10	10	9	9
25	42.5	7	8	8	14	14
30	50	6	7	7	14	23
40	65	4	5	6	23	23
50	81.25	2	3	4	30	40
60	96.25	1	2	3	40	50
75	120	2/0	1/0	1	60	75
100	155	3/0	2/0	1/0	100	100
125	195	250	4/0	3/0	125	150
150	225	300	250	4/0	150	200
200	300	500	400	300	250	300

(1) Examples of AC Motor Circuits. Examples of 3-Phase AC Motor Circuits (reference 3.G.15.e). Use Quick-Reference Columns, Figure 1 above:

(a) Example No. 1. Single motor, 25 horsepower, 460V, code letter J, full voltage start, non-adjustable overloads, branch circuit breaker, Type T, IEEE 45 Cable, in 50 C ambient temperature space.
From Quick-Reference Columns, Figure 1:

D – Standard overload size nearest 115 percent full load; current is 40 amperes.

E – Starter size is 2.

F – If a disconnect is used near the motor, a 100 ampere size is sufficient, provided it is not fused above 100 amperes (if fusible). If part of a combination starter, the complete unit must be rated to handle the 25-horsepower motor.

I – The maximum standard size for the branch circuit protective device is a 90 ampere breaker.

3.G.15.e(1) (a) (cont'd) L – The cable used to power the motor must be rated for at least 42.5 amperes. For Type T cable in a 50 C ambient location Type T-7 is required

(b) Example No. 2. A 460 volt Motor Control Center (MCC) supplying one 30 HP, one 15 HP, and two 5 HP motors in 50 C ambient space. One 5 HP motor is a steering system pump. All are full-voltage starting; the 30 HP motor starter has protection with circuit breakers. Navy-type cable TSGA is used. First get data for each load; assume code letters F-V.

Quick-Reference Columns, Figure 2:							
Col. A	Col. B	Col. C	Col. E	Col. F	Col. I	Col. K	Col. P
HP	Full Load Amps	Adj. Over Load Size	Starter Size	Std. Disc. Size, If Used	Max. Branch Circ. Bkr (250%)	125% F.L.A.	50 C TSGA -()
30	40	46	3	100	100	50	23
15	21	24.2	2	60	60	26.3	9
5	7.6	8.7	0	30	N/A	9.5	4

Subchapter J does not address motor control centers directly; one must refer to NEC 430-24 and 430-62(a). Per 430-24, bus or cable in MCC must be sized for 125 percent of the largest plus 100 percent of the remaining motor full load currents, 50+21+7.6+7.6 = 86.2 amperes. If the MCC has spare sections, allowance shall be made for future growth. Breaker protecting entire MCC must not be larger than the largest rating or setting of the branch-circuit short-circuit and ground fault protection (based on Table 430-152) for any motor in the group, or 100+ 21+ 7.6+7.6 = 136.2 amperes.

A 125 amp circuit breaker would be adequate.

The 5 HP steering pump motor should be protected with a circuit breaker having adjustable, instantaneous (magnetic) type tripping only. This breaker must be set to open the motor circuit at 175 to 200 % of the locked rotor current. As will be shown, this setting should be 79 to 90 amperes.

(2) Tables.

NEMA AC General purpose, Class A Full Voltage Controllers, Single-Speed Squirrel Cage Motors.					
3-Phase Non-Jogging Duty					
Size	Continuous Duty Amps	200 VAC	Horsepower 230 VAC	460 VAC	Limit Amps
00	9	1.5	1.5	2	11
0	18	3	3	5	21
1	27	7.5	7.5	10	32
2	45	10	15	25	52
3	90	25	30	50	104
4	135	40	50	100	156
5	270	75	100	200	311
6	540	150	200	400	621
7	810		300	600	932

3.G.15.e(2) (cont'd)

3-Phase Jogging Duty					
Size	Continuous Duty Amps	200 VAC	Horsepower 230 VAC	460 VAC	Limit Amps
0	18	1.5	1.5	2	21
1	27	3	3	5	32
2	45	7.5	10	15	52
3	90	15	20	30	104
4	135	25	30	60	156
5	270	60	75	150	311
6	540	125	150	300	621

Note: From NEMA ICS 2-321 B

Motor Conversion Formulas.			
TO FIND	DC	AC - Single Phase	AC 3 Phase
AMPS when HP is known	$\frac{HP \times 746}{Volts \times Eff}$	$\frac{HP \times 746}{Volts \times Eff \times PF}$	$\frac{HP \times 746}{Volts \times 1.73 \times Eff \times PF}$
AMPS when KW is known	$\frac{KW \times 1000}{Volts}$	$\frac{KW \times 1000}{Volts \times PF}$	$\frac{KW \times 1000}{Volts \times 1.73 \times PF}$
AMPS when KVA is known		$\frac{KVA \times 1000}{Volts}$	$\frac{KVA \times 1000}{Volts \times 1.73}$
Kilowatts KW	$\frac{AMPS \times Volts}{1000}$	$\frac{AMPS \times Volts \times PF}{1000}$	$\frac{AMPS \times Volts \times 1.73 \times PF}{1000}$
KVA		AMPS x Volts	AMPS x Volts x 1.73
Power Factor PF		$\frac{KW}{KVA}$	$\frac{KW}{KVA}$
HP Output	$\frac{AMPS \times Volts \times Eff}{746}$	$\frac{AMPS \times Volts \times Eff \times PF}{746}$	$\frac{AMPS \times Volts \times 1.73 \times Eff \times PF}{746}$

Notes: (1) Power Factor and Efficiency should be expressed in decimals.

(2) If Power Factor is not given, assume 0.8.

(3) If Efficiency is not given, assume 0.8.

Single Phase Motor: Approximate Full Load Current.			
HP	115V	HP	115V
.33	7.2	2	24.0
.5	9.8	3	34.0
.75	13.8	5	56.0
1.0	16.0	7.5	80.0
1.5	20.0	10	100.0

Notes: (1) Values are for motors of normal speed and torque.

(2) For additional values, see NEC Table 430-148.

(3) For other KW ratings, voltages, and power factors:

$$AMPS = \frac{KW \times 1000}{1.732 \times Volts \times PF}$$

3.G.15.e(2) (cont'd)

Motor Locked Rotor Current.												
Max.	115VAC 1 Phase			208VAC 3 Phase			230VAC 3 Phase			460VAC 3 Phase		
HP	100%	175%	200%	100%	175%	200%	100%	175%	200%	100%	175%	200%
2	144	252	288	43	75	86	39	68	78	20	35	40
3	204	357	408	59	103	118	54	95	108	27	47	54
5	336	588	672	99	173	198	90	158	180	45	79	90
7.5	480	840	960	145	254	290	132	231	264	66	116	132
10	600	1050	1200	178	312	356	162	284	324	84	147	168
15				264	462	528	240	420	480	120	210	240
20				343	599	686	312	546	624	156	273	312
25				422	739	844	384	672	768	192	336	384
30				515	901	1030	468	819	936	234	410	468
40				686	1201	1372	624	1092	1248	312	546	624
50				825	1444	1650	750	1313	1500	378	662	756
75				1221	2137	2442	110	1943	2220	558	977	1116
100				1624	2874	3248	1476	2583	2952	738	1292	1476

Notes: (1) These values are to be used only if motor code letter is not provided.

(2) Values above calculated from NEC Tables 430-150, 430-151.

(3) If motor nameplate code letter is provided, the following applies

(a) See NEC Table 430-7(b) for code letter KVA/HP; and

(b) Locked rotor current, IL:

$$\text{3-phase motors IL} = \frac{\text{HP x (KVA/HP) x 1000}}{\text{1.73 x Volts}}$$

$$= \frac{\text{577 x HP x (KVA/HP)}}{\text{Volts}}$$

$$\text{1-phase motors IL} = \frac{\text{HP x (KVA/HP) x 1000}}{\text{Volts}}$$

3.G.15.e(2) (cont'd)

Continuous-Duty, 3-Phase Motor Approximate F.L.A.						
HP	Squirrel Cage			Wound Rotor		
	208V	220V	440V	208V	220V	440V
.5	2.1	1.9	.95			1.0
1	3.7	3.4	1.7	5.9	5.4	2.7
1.5	5.5	5.0	2.5	7.5	6.8	3.4
2.0	6.9	6.3	3.1	8.8	8.0	4.0
2.5	8.4	7.6	3.8	9.7	8.8	4.4
3.0	9.9	9.0	4.5	11.5	10.5	5.3
5.0	16.0	14.5	7.2	17.6	16.0	8.0
6.0	18.9	17.2	8.6	19.8	18.0	9.0
7.5	23	21	10.5	25.3	23	11.5
9.0	27.3	24.8	12.4	28.6	26	13
10	28.6	26	13.5	31.9	29	14.5
20	57.2	52	26	59	54	27
25	71.5	65	32	75	68	34
30	86	78	39	88	80	40
35	101	92	46	103	94	47
40	112	102	51	114	104	52
45	128	116	58	128	116	58
50	139	126	63	141	128	64
60	167	152	76	169	154	77
75	207	188	94	207	188	94
100	275	250	125	275	250	125
125	341	310	155	341	310	155
150	407	370	185	407	370	185
200	539	490	245	539	490	245

Notes: (1) To be used in lieu of nameplate data (see NEC 430-6).

(2) Not to be used to size motor running overloads; use nameplate data.

(3) For multi-speed, low speed, special motors, use nameplate data.

(4) For additional information, see NEC Table 430-150.

(5) Ranges: 220V 220-240VAC
440V 440-480VAC

16. Navigation Lights (46 CFR 111.75-17).

a. General. Annex I of the International Regulations for Preventing Collisions at Sea, 1972, (72 COLREGS) and the 1980 Inland Navigation Rules, (80 RULES), specify navigation light requirements in terms of color, arcs, range of visibility, and position. Lights that act as aids to navigation, such as lights on a dredge pipeline, do not have to meet 46 CFR 111.75-17. The regulations for these lights are found in 33 CFR 88.15.

b. Fixtures & Fixture Marking. Label fixtures in accordance with 46 CFR 111.75-20. The regulations applicable to electric navigation light fixtures are also contained in 46 CFR 111.75-17. There are no

3.G.16 b. (cont'd) regulations that specifically prohibit the use of non-electric lights, except where the use of open flames is prohibited. However, the requirement for a navigation light indicator panel generally precludes the use of non-electric lights on vessels subject to the requirements of Subchapter J.

c. Horizontal Sector. Annex I of both sets of Rules gives specific arcs in which certain intensities of light are required. For example, sidelights as fitted on the vessel must, in the forward direction, reach "practical cut-off" (i.e., one-eighth of the minimum required sector intensity) between 1 and 3 degrees outside the prescribed sector. The 72 COLREGS have been interpreted as requiring the intensity between 0 and 1 degrees outside the prescribed sector to be greater than the practical cut-off value. This allows both sidelights to be visible dead ahead of the vessel, at a distance dependent upon their separation. This may present a problem for some vessels. For example, containers stacked forward of the sidelights could act as large screens, preventing the 1-degree "spillover." A Certificate of Alternative Compliance (CAC) is not appropriate in such cases; the lights should be relocated or the obstruction removed.

d. Vertical Sector. Annex I of both sets of Rules also establishes requirements for vertical sectors of navigation lights. Previously, this parameter was not even considered.

e. Masthead Separation. Masthead lights must be separated by a horizontal distance of one-half the length of the vessel but the separation need not be more than 100 meters (Annex I 3.(a)). Most vessels with a midship house were built with the after mast located amidships and will not meet this separation requirement without moving the mast(s). Also, moving the after mast from the midship house to the after house generally requires the after mast to be higher than original to meet height separation requirements. For this reason, Rule 38 permanently exempted vessels under 150 meters (492.1 ft.) and gave larger vessels 9 years to comply.

This extension was made with two-house vessels in mind and in consideration of the economic hardships involved with moving/raising masts. Therefore, CAC's would not be appropriate for masthead separation unless moving the masts would interfere with the special purpose of the vessel.

f. Sidelight Placement. Sidelights must not be "in front" of the forward masthead light (Annex I 2(g), 3(b)). This rule also applies to single masted vessels and will require sidelight repositioning on many vessels in the 20-50 meter range. Some vessels (i.e., tugboats, workboats, or fishing vessels) may qualify for CAC's due to the special purpose of the vessel.

Acceptance and conformance to Underwriters Laboratories Inc. standard UL 1104 is based on the requirements of the 72 COLREGS and construction requirements that address lighting fixtures in weather locations. The regulations do not require UL listing of navigation light fixtures; they require that the fixtures meet the UL standard. This allows the manufacturer to do their own testing and submit the reports for acceptance.

3.G.16 f. (cont'd) Premature bulb failure on vessels such as tugs and barges, problems with vibration and shock (impact) have been reported. Although navigation lights are subjected to stringent vibration testing, with bulb failure as a rejection factor (evidenced by one manufacturer failing this test and having to re-design the fixtures), the accepted fixtures are not tested for impact shock. When shock or vibration is a problem, shock mounting the fixture is recommended. This shock mounting can take two forms. The first is internal isolation of the bulb. This is a manufacturer's modification and could involve retesting of the fixture. The second is to isolation mount the fixture on the vessel.

Another factor that has contributed to premature failure of lamps is inadequate voltage regulation. A 10% increase in voltage will reduce bulb life to approximately 25% of its rated life. Thus, any action to ensure proper voltage at the fixture will help to extend bulb life.

Screens. Annex I of the International Regulations for Preventing Collision at Sea, 1972 (72 COLREGS) and Annex I of the 1980 Inland Navigation Rules require sidelights on vessels over 20 meters in length to have external screens. These screens are to be painted matte black. Therefore, all sidelight fixtures on U.S. Coast Guard certificated vessels greater than 20 meters in length must have screens painted matte black for the sidelights.

The sidelight screens may be utilized to obtain the required cut-off angles for the sidelights as required by Section 9 of Annex I to the 72 COLREGS and section §84.17 of the 1980 Inland Rules. If the sidelight fixtures are fitted with internal screens that provide the proper cut-off angles, an external screen must still be provided to meet the 72 COLREGS as well as the Inland Rules. The installation of an internally screened sidelight in conjunction with an inboard external screen, if properly aligned, would meet the requirements.

In addition to sidelights, other navigation lights (such as masthead and anchor) have horizontal sector cut-off requirements. Most manufacturers have used internal screens to achieve the required cut-off, but external screens would also be acceptable, although they are not required. These fixtures would be required to be marked with an indication that they are to be installed with external screens.

g. <u>Barge Lights (Battery Powered) Exemptions</u>. International Regulations for Preventing Collisions at Sea, 1972, (72 COLREGS); Lights for Unmanned Barges, COMDTINST M16672.3 (series) has exempted battery powered barge lights from the vertical sector cut-off requirements of the 72 COLREGS. It is only applicable to unmanned barges without machinery for the generation of electricity or with such machinery intended for operation only while moored. The 1980 Inland Rules permanently exempt electric navigation lights on unmanned barges from the vertical sector requirements.

17. <u>Hazardous Locations (46 CFR 111.105)</u>.

a. <u>General</u>. Where flammable gases or vapors may be present, such as on the drill floor of a Mobile Offshore Drilling Unit or in the pumproom of a tankship, special precautions must be taken to ensure that

3.G.17 a. (cont'd) electrical equipment is not a source of ignition. Subpart 111.105 of the Electrical Engineering Regulations contains the requirements for electrical equipment and wiring in locations where fire or explosion hazards may exist. In these locations, it is necessary to exercise more than ordinary care with regard to the selection, installation, and maintenance of electrical equipment and wiring. A primary objective of design should be to minimize the amount of electrical equipment installed in hazardous locations. Through the exercise of ingenuity in the layout of electrical installations for hazardous locations, it is frequently possible to locate much of the equipment in less hazardous or in non-hazardous areas and thus reduce the amount of special equipment and installations required.

b. Protection Types. The various methods by which electrical and electronic equipment is made safe for use in hazardous areas may be divided into two major categories: (1) protection by enclosure or other physical separation between the electrical equipment and the hazardous atmosphere; and (2) protection by electrical design (making the circuitry unlikely to produce ignition of the hazardous atmosphere). Examples of the first category include explosion-proof and purged and pressurized enclosures, as well as oil immersion. The second category includes the intrinsically safe and nonincendive safety techniques.

(1) Ignition Protection. Ignition-protection is another type of protection by design. Ignition-protected devices are intended for use aboard recreational boats and uninspected vessels in enclosed spaces that may occasionally contain gasoline vapors. They meet the testing requirements of UL 1500, which are not as stringent as those for explosion-proof or intrinsically safe equipment. Ignition-protected equipment is not suitable for use in hazardous locations on inspected vessels other than oil recovery vessels.

(2) Intrinsically Safe. This is the only method that uses electrical protective measures to prevent ignition from electrical faults. Intrinsically safe equipment is used in both Zones 0 and 1 and Division 1 areas.

(3) Explosion Proof Vs. Flame Proof. Explosion proof enclosures are used in the U.S. and Canada while flameproof enclosures are used elsewhere. Both types of enclosure have flame paths that cool the gases as they escape from the enclosure. What is notable here is that flameproof equipment is designed to meet IEC 60079-1 and/or CENELEC Standard EN50018. With a choice of standards to conform to, there are varying differences in flameproof equipment from country to country.

(4) Type "n" Protection. Type of Protection "n"- (Article 505 of the NEC and IEC 60079-15) Type "n": protection is a type of protection applied to electrical equipment such that in normal operation, the electrical equipment is not capable of igniting in a surrounding explosive gas atmosphere and a fault capable of causing ignition is not likely to occur. This type of equipment is allowed in Europe, U.S. and Canada in Class 1 Zone 2 areas.

3.G.17 c. Classification. National and international codes and regulations classify materials and locations based upon the experimentally determined properties of flammable vapors, gases, liquids, or combustible dusts or fibers that may be present and the likelihood that a flammable or combustible concentration or quantity is present. North American standards identify hazardous locations by Class and Division using the scheme described in Tables 1 and 2 (3.G.17.f). International standards (such as IEC Standard 60079-10) use a different nomenclature, but their classification philosophy is mostly the same.

For Class I locations, gases and vapors are divided into groups A, B, C, or D, depending upon experimentally determined maximum explosion pressure, maximum safe clearance between parts of a clamped joint in an enclosure, and the minimum ignition temperature of the atmospheric mixture. For Class II locations, dusts are divided into Groups E, F, and C, depending upon the tightness of the joints of assembly and shaft openings for preventing entrance of dust into the dust/ignition proof enclosure, the blanketing effect of layers of dust on the equipment that may cause overheating, electrical conductivity of the dust and the ignition temperature of the dust. In general, equipment must be approved not only for the Class, but also for the specific Group of the gas, vapor, or dust that may be present. Flammable and combustible liquid cargoes may be further classified according to their vapor pressure and flashpoint. These liquids may be assigned both a Group and a Grade (Grade designation relates to flashpoint). In cases where differing requirements apply or several different hazardous atmospheres may be present, the most hazardous condition is presumed to exist and the most restrictive requirements should be applied.

Once a specific location is classified, and specific materials that may be present are identified, the permitted types of electrical equipment are easily determined. For example, an area containing gasoline vapors would require Class I, Group D equipment. Where vapors would be present under normal conditions, the area would be a classified as Division 1, and equipment must be suitable for use in a Class I, Division 1, Group D location.

This classification system requires the use of some individual judgment, especially in the designation of "Division." To promote consistency and ensure safety, standard setting bodies and regulatory agencies have developed detailed standards, recommended practices, codes, and regulations applicable to specific situations.

The IEC 60079-XX “Electrical apparatus for explosive gas atmospheres” series of standards are based upon the concept of Zones. These standards separate the North American classification of Division I into Zone 0 and Zone 1. Zone 0 identifies those areas where “flammable gases are present continuously or for long periods of time and takes more restrictive measures to protect against electrical ignition”. Thus only intrinsically safe apparatus or equipment can be used. Explosion-proof and pressurized equipment are not allowed for use in Zone 0 classified areas.

Zone 1 is classified as less hazardous then Division 1. In an area classified as Zone 1, less restrictive practices other than explosion

3.G.17 c. (cont'd) proof or purging can be used. Arcing devices, however, must still be housed inside explosion-proof enclosures.

d. Specific Hazardous Areas. Locations where flammable gases or vapors can exist on commercial vessels include battery rooms, paint lockers, pumprooms and weather deck locations above cargo tanks on tank vessels, mud pit rooms and the drill floor of Mobile Offshore Drilling Units, and operating rooms where anesthetics are administered on passenger vessels and hospital ships. 46 CFR 111.105 defines specific hazardous locations for combustible liquid cargo vessels, flammable liquid cargo vessels, liquid sulphur carriers, inorganic acid tankships, bulk liquefied gas and ammonia carriers, MODU's, vessels carrying coal, and vessels (such as ferries and RO-RO's) with spaces for the carriage of vehicles using gasoline or other highly volatile motor fuels. Typical hazardous location classifications are illustrated in section 3.G.17.d (7). Note the IEC "Zone" approach is also allowed by 46 CFR 111.105 and the NEC.

The Electrical Engineering Regulations define particular areas to be Division 1 or Division 2 locations; there is no "Division 0" in the Division scheme comparable to the IEC Zone 0 designation. In the Division scheme, spaces where the hazard is assumed to be present under normal conditions are classified as Division 1 locations. There is no "higher" classification (i.e., Division 0). Enclosed locations comparable to tank vessel pumprooms typically do not exist in National Electrical Code applications. On shore, such installations are usually located in the weather, and spread-out over a much larger area. In Coast Guard regulations, spaces comparable to "Zone 0" locations such as pumprooms on tank vessels, while not given a Division 0 designation, are permitted only limited electrical equipment (i.e. explosion-proof lights, intrinsically safe systems, and cables) similar to IEC Zone 0 requirements.

Combustible liquids (see definition in 46 CFR 30.10-15) are often referred to as Grade D and Grade E cargoes. Similarly, flammable liquids (defined in 46 CFR 30.10-22) may be classified as Grade A, B, or C cargoes. Due to the high flashpoints of Grade E liquids, vessels carrying only Grade E cargoes need only meet the requirements of 46 CFR 111.105-29 for combustible liquid cargo carriers. The requirements of 111.105-31 apply to vessels carrying combustible or flammable cargo with a closed-cup flashpoint lower than 60°C (140°F), as well as liquid sulphur and inorganic acids. Note that in accordance with 46 CFR 30.10-15 Grade D cargo may fall above or below the 140°F cutoff. Flammable hydrogen sulfide gas evolves from liquid sulphur, and many inorganic acids produce hydrogen gas when in contact with a number of common construction metals.

(1) MODU's. On MODU's, a specific classification for crude oil cannot always be given, since crude is a mixture of widely varying hydrocarbons. Locations are usually, however, designated Group D due to the presence of natural gas. Hydrogen sulfide, which is frequently encountered during drilling operations, has a Group C designation. Drilling operators often utilize electrical equipment that is suitable for both hazard groups C and D, especially when this equipment is readily available, and there is no economic penalty. It should not be inferred from the presence of some Group C equipment that the area has been classified as a

3.G.17.d (1) (cont'd) Group C area. A Group D classification should be adequate when drilling in a region where the known or suspected mixture of hydrogen sulfide and natural gas is less than 25 percent hydrogen sulfide (by volume). Coal carriers and vessels carrying bulk grain and other agricultural products may be subject to dust explosion hazards. Just as with flammable gas or vapor explosions, the initial ignition source of a dust explosion may be a small spark or flame. However, an initial explosion may dislodge settled dust from the surrounding area that may then be ignited by the residual energy to cause a second and larger explosion.

Undispersed dust that has accumulated in layers will not explode but may burn or char; generating heat that may ignite dispersed dust. NEC Article 502 lists the primary hazards that must be avoided as the admission of dusts into electrical equipment enclosures, reaching the heat of ignition due to the insulating characteristics of accumulated dust, and the formation of current paths of conductive dusts.

Explosion hazards due to agricultural dusts are not specifically addressed in the Electrical Engineering Regulations. However, 46 CFR 111.105-17 and 111.105-35 do give the requirements for electrical installations in Class II locations and specific requirements for vessels carrying coal. NVIC 9-84

(2) Agricultural Dust Areas. Electrical Installations in Agricultural Dust Locations further defines the classification of hazardous areas due to agricultural dusts. It must be remembered that the enclosure protection method is different for dust than it is for a gas or vapor, and that "dust ignition-proof" and "explosion-proof" are two different concepts. For a dust, the enclosure keeps dust out and does not build-up excessive temperatures when blanketed with dust. For a vapor, the enclosure allows vapor to enter and be ignited, yet prevents the internal explosion from propagating to the surrounding atmosphere. Equipment acceptable for use in a dust atmosphere is not generally suitable for use in a gas atmosphere, and vice-versa.

(3) Coal. Vessels carrying coal may be subject to the double hazard of explosive gas as well as explosive dust. Freshly mined coal releases methane gas that had been contained within the pores of the coal. Release of methane can continue for days and even weeks after the coal is mined. If freshly mined coal is stored in an enclosed space, such as a bunker or closed hold on a ship, this methane may collect in sufficient quantity to cause an explosion.

(4) Battery & Paint Stowage Rooms. Battery rooms and paint stowage or mixing spaces must meet the electrical requirements of 46 CFR 111.15 and 111.105-41 & 43, respectively. The regulations do not explicitly state that these spaces are defined as hazardous. However, equipment within these spaces must be suitable for installation in Division 1, Zone 0 or Zone 1 locations. The hazardous locations are considered to exist only inside these spaces; the regulations do not define a hazardous area as extending any specific radius from doors, hatches, or other openings into these spaces. The use of only explosion-proof or

3.G.17.d (4) (cont'd) intrinsically safe electrical equipment and the avoidance of open flames and sparking near such openings is, however, strongly recommended.

(5) Armored Or Mineral Insulated Cable. The Electrical Engineering Regulations require armored or mineral insulated cable for most installations in hazardous locations. Unarmored cable is permitted for intrinsically safe systems, portable equipment, applications requiring flexible cable, and in Division 2 locations. Industrial systems may use an armored type cable construction, but the cable must also meet the installation and flammability test requirements of 46 CFR 111.107-1(c) if it penetrates a deck or bulkhead. Conduit systems that meet the applicable requirements of the NEC provide an equivalent level of safety and can be permitted.

(6) Stowage Of Vehicles With Gasoline In Tanks. The minimum safety requirements for electrical equipment located in spaces intended for the stowage of vehicles with gasoline in their tanks and batteries connected are contained in 46 CFR 111.105-39. These requirements apply to spaces designated as specially suitable for vehicles" on passenger and cargo vessels It should be noted that SOLAS II-2/37.1.6, 37.2.2, and 37.3.2 contain somewhat different requirements for ventilation and precautions against ignition of flammable vapors in "special category spaces", which are those vehicle stowage spaces on passenger vessels normally accessible to passengers. Regulations 38.3 and 38.4 address these issues for other vehicle cargo spaces on passenger vessels. Similarly, SOLAS 11-2/53.2.3 and 53.2.4 state the ventilation and ignition prevention requirements for vehicle spaces on cargo vessels, including RO/RO spaces. While 46 CFR 111.105-39 is considered to provide sufficient minimum requirements for the prevention of ignition by electrical equipment, closed spaces for fueled vehicles should be provided with ventilation per ABS Section 5-10-4/3 and SOLAS 11-2/53.2.3.

(7) Specified Hazardous Location Table.

Specified Hazardous Locations				
Locations	Class I Div. 1	Class I Div.2	Class II	Class III
Cargo Tanks*	NA	NA	NA	NA
Cargo Handling Rooms*	NA	NA	NA	NA
Cofferdams*	NA	NA	NA	NA
Battery Rooms	X	NA	NA	NA
Paint Storage Rooms	X	NA	NA	NA
Paint Mixing Rooms	X	NA	NA	NA
Oil Storage Rooms	X	NA	NA	NA
Anesthetic Handling Area	X	NA	NA	NA
Tank Vessel Weather deck 10 ft. Rule	X	NA	NA	NA
Tank Vessel Weather deck Cargo Block	X	NA	NA	NA
Flammable Gas Handling Room*	NA	NA	NA	NA

Specified Hazardous Locations				
Locations	Class I Div. 1	Class I Div.2	Class II	Class III
Flammable Liquid Handling Room*	NA	NA	NA	NA
Adjacent to Class I, Div. 1 w/Communication	X	NA	NA	NA
Tank Vessel Enclosed Space Adjacent to Cargo Tank*	NA	NA	NA	NA
Grain Handling Area	NA	NA	X	NA
Coal Handling Area	NA	NA	X	NA
Coal Pulverizing Area	NA	NA	X	NA
Carpenter Shop	NA	NA	NA	X
Fiber Handling Area	NA	NA	NA	X
Vent Duct	Same as Space Served			
Tank Vessel Cargo Hose Stowage Space*	NA	NA	NA	NA
Space Containing Cargo Piping only, on Tank Vessels*	NA	NA	NA	NA
LFG Barrier Space*	NA	NA	NA	NA
Enclosed Space Opening to Weather Deck Haz. Area	X	NA	NA	NA
Tank Vessels Within 8’ of Cargo Containment System	X	NA	NA	NA
Tank Vessels, Within 10’ of Cargo Handling Room Door or Vent	X	NA	NA	NA
Vessel Fuel Oil Tanks, 10’ Rule Does not Apply	X	NA	NA	NA
Tank Vessel, A-D Cargoes, Area From 3m to 5m of PV Valves	(see SOLAS II-2/59.1.7.2)			
	NA	X	NA	NA
Tank Vessel, A-D Cargoes, Area From 3m to 10m of Vent Outlets for Free Flow of Vapors and H.V. Vents for Loading or Discharge	(see SOLAS II-2/59.1.9.3)			
	NA	X	NA	NA

Note: These areas are considered more hazardous than Class I, Division 1 and therefore carry specific requirements in 46 CFR 111.105-29, 111.105-31, and 111.105-32

e. Electric Heat Tracing. Questions frequently arise concerning the acceptability of electric heat tracing in hazardous locations. Heat tracing is permitted in Division 2 locations by NEC Article 501-10(b)(1). Since the NEC requires wiring in Division 1 locations to be in conduit, it does not recognize heat tracing cable installations in Division 1 locations. However, since shipboard Division 1 installations use cable, not conduit, and Subchapter J does not reference the NEC for Division 1 wiring methods, electric heat tracing may be used in Class I Division 1 locations. The heating cable must not exceed 80% of the auto-ignition temperature in degrees Celsius of any gas or vapor involved on any surface, which is exposed to the gas or vapor, when continuously energized at the maximum rated ambient temperature. Any thermostats, controllers, power supplies, 3.G.17 e. (cont'd) and other associated equipment must be provided with enclosures approved for Class I Division 1 locations or be located outside of the designated hazardous areas.

f. Hazardous Area Drawings. Hazardous area drawings and a corresponding bill of materials are normally reviewed by the Marine Safety Center, or cognizant OCMI, prior to the installation of any electrical equipment in a hazardous location. Hazardous area drawings and equipment lists should be maintained to reflect the current arrangement and inventory of electrical equipment in those locations.

A proper hazardous area drawing is an arrangement plan showing the boundaries and classification of all hazardous areas, and the location of all electrical equipment in those areas. It should be accompanied by a bill of material or equipment list that identifies each item by manufacturer, model number, and Class and Group for which approved, and should provide evidence of approval by a nationally recognized testing laboratory. In addition, the operating temperature of the electrical equipment must not exceed the auto-ignition temperature of the gases or vapors likely to be present. Confirmation of equipment temperature is usually beyond plan review capabilities, since it is not usually provided in approval listings. This information is required on the label of explosion-proof equipment in the form of an operating temperature identification code number on the equipment if the temperature exceeds 100 degrees C. (see Table 3 at 3.G.17.j(2)). Normally, the only equipment installed in hazardous locations having a temperature code will be incandescent lighting fixtures and motors. When such equipment is used in a machinery space, a 50 degrees C. ambient is assumed. The labeled operating temperature is usually referenced to a 40 degree C. ambient. Unless the equipment has thermally actuated sensors that limit the operating temperature to that specified on the label, equipment in high ambient temperature locations should be derated.

NVIC 8-84, "Recommendations for the Submittal of Merchant Vessel Plans and Specifications" provide additional guidance on hazardous area submittals.

RECOMMENDED PLAN REVIEW CHECK-OFF FOR HAZARDOUS LOCATIONS

1. Has sufficient information been provided?

(a) Hazardous cargoes;

(b) An arrangement plan identifying hazardous and non-hazardous areas, cargo system or hazards, electrical equipment type and locations;

(c) A complete and detailed Bill of Materials;

(d) Elementary and one-line wiring diagrams, showing all wiring;

(e) Electrical installation details;

(f) Nationally Recognized Testing Laboratory (NRTL) label or listing for explosion proof (EP) and intrinsically safe (Is) equipment and systems; and

3.G.17.f.1 (g) Maximum temperature ratings of electrical equipment in hazardous areas.

2. Identify hazardous characteristics:

(a) Class and group;

(b) Flashpoint and grade;

(c) Minimum ignition temperatures; and

(d) Special requirements, including material compatibility.

3. Confirm boundaries of hazardous locations and suitability of equipment installed.

4. Confirm that the installation meets:

(a) Subchapter J;

(b) Intended application by a NRTL (currently UL, FM, CSA, and MET are Acceptable to the Coast Guard)

(c) Specific requirements for the cargo/material; and

(d) General considerations of this NVIC.

Table 1

Classification of Properties of Hazard-Producing Materials

Class I -- Locations where flammable gases or vapors may be present, including:

Group A: Atmospheres containing acetylene.
Group B: Atmospheres such as butadiene, ethylene oxide, propylene oxide, acrolein, or hydrogen (or gases or vapors equivalent in hazard to hydrogen)
Group C: Atmospheres such as cyclopropane, ethyl ether, ethylene, or gases or vapors of equivalent hazard.
Group D: Atmospheres such as acetone, alcohol, ammonia, benzene, benzol, butane, gasoline, hexane, lacquer solvent vapors, naphtha, natural gas, propane, or gases or vapors of equivalent hazard.

Class II -- Locations where combustible dust may be present, including:

Group E: Atmospheres containing combustible metal dusts or other combustible dusts or similarly hazardous characteristics.

Group F: Atmospheres containing combustible carbon black, charcoal, coal, or coke dusts.
Group G: Atmospheres containing combustible agricultural or plastic dusts.

Class III -- Locations where easily ignitable fibers or flyings, such as cotton fibers, sawdust, and wood shavings, may be present.

3.G.17.f (cont'd)

Table 2

Classification of the Probability that Material May Be Present in Flammable or Combustible Quantities

Division 1: (Zone 1)	Where material can exist under normal operating conditions, or frequently because of repair, maintenance, or leakage.
Division 2: (Zone 2)	Where material can exist under abnormal conditions (accidental rupture or breakdown, abnormal operations, etc.), or locations adjacent to a Division 1 location where material may occasionally be present.

Note: International standards use the term "Zone" instead of "Division" and include a "Zone 0" designation for locations where vapors are assumed to be present, such as inside a tank or in a tankship pumproom. A comparable "Division 0" does not exist in the Division classification scheme. Coast Guard regulations achieve the same effect as a “Division 0” by limiting electrical installations in applicable locations to the type permitted for Zone 0 locations. Many domestic standards as well as Coast Guard regulations now include the Zone approach.

g. Equipment. Specific requirements for electrical equipment in hazardous locations are contained in 46 CFR 111.105. In that subpart, certain equipment is required to be listed an independent laboratory recognized by the Commandant (G-MSE-3) for use in the hazardous location in which it is located. "Listed" means equipment included in a list published by an U.S. Coast Guard accepted independent test laboratory concerned with product evaluation, that maintains periodic inspection of listed equipment and whose listing states either that the equipment meets appropriate standards or has been tested and found suitable for use in a specified manner.

(1) Division 1 Equipment. The following general considerations apply to equipment selection and installation: Division 1 equipment is satisfactory for Division 2 applications with the same Class and Group. Note that the explosion-proof equipment label may not say "Division I." If the label says it is suitable for Class I Group (__) locations, it means it is suitable for both Division 1 and Division 2 locations.

(2) Class 1 Division 2 Make And Break Contacts. NEC Section 501-3(b)(l) requires devices in Class I, Division 2 locations, with make-and-break contacts to be within an enclosure approved for Class I, Division 1 locations or to be in a general-purpose enclosure with the current interrupting contacts either immersed in oil, enclosed in a hermetically sealed chamber, or in only nonincendive circuits.

Examples of make-and-break contacts include relays, circuit breakers, servo-potentiometers, adjustable resistors, switches, connectors, and motor brushes. A nonincendive circuit is a

3.G.17.g (2) (cont'd) circuit in which any arc or thermal effect produced under intended operating conditions of the equipment is not capable of igniting the specified flammable gas or vapor-air mixture. A hermetically sealed device is one which is manufactured so that it is completely sealed against entrance of an external atmosphere and in which the seal is made by soldering, brazing, welding, or fusion of glass, or the like.

(3) General Purpose Enclosures. NEC Section 501-3(b)(2) permits general-purpose enclosures to be used in Class I, Division 2 locations for resistance devices and similar equipment used with meters, instruments, and relays provided such equipment is without make-and-break or sliding contacts and the maximum operating temperature of any exposed surface will not exceed 80% of the ignition temperature of the gas or vapor involved.

(4) Belt Drives. Belt drives are acceptable if the belt is conductive and the equipment is grounded in accordance with NFPA 77. Acceptable belts have a resistance of approximately 6 mega ohms or less over an eight inch length, as determined by an industry standard test procedure, and are commonly designated as "static conductive."

(5) Cables. Cables must not be located in any tanks containing flammable or combustible liquids, except to supply equipment or instrumentation specifically designed for, and compatible with, such location, and whose function requires installation in that location.

(6) Vent Ducts. Vent ducts have the same classification as the space they serve. Fans for ventilating hazardous locations must be nonsparking as defined in ABS 4-8-3/11. Nonsparking construction is not generally indicated by an independent laboratory listing, and must usually be verified by review and/or inspection. Vent fan motors must either be approved for the hazardous location or located outside the duct, 10 feet from the duct termination, in a non-hazardous area.

(7) Alloys. Alloys of aluminum, magnesium, and titanium, when struck by rusty steel, react with the iron oxide to produce a highly exothermic "thermite reaction." Care must be taken to provide adequate physical separation and/or surface coatings where these metals are used in moving components around steel. The most important thing to remember is that equipment rated for Division 1 or 2 can be used in Zone 1 or 2 respectively. However, equipment rated for Zones cannot be installed in areas classified as Division 1 or 2.

h. Intrinsic Safety and Nonincendive Systems. For low power applications, such as instrumentation, control, and operation of solenoid valves, the use of intrinsically safe and nonincendive systems can reduce the likelihood of fire or explosion due to the ignition of flammable gas mixtures by electrical arcs or high temperatures. However, safety depends on their proper application, as these two forms of protection are not equal.

3.G.17 h. (cont'd) Section 501-3 of the NEC states: In Class 1, Division 2 locations, switches, circuit breakers, and make-and-break contacts shall have enclosures approved for Class 1, Division 1 locations. EXCEPTION: General-purpose enclosures shall be permitted, if current-interrupting contacts are... in circuits that under normal conditions (emphasis added) do not release sufficient energy to ignite a specific ignitable atmospheric mixture, i.e., are nonincendive. The word "nonincendive" means that under the conditions specified, there is insufficient energy to cause ignition. Nonincendive systems are only permitted in Division 2 and non-hazardous locations.

(1) <u>Nonincendive Systems</u>. Nonincendive circuits are similar to intrinsically safe circuits, but no fault conditions or safety factors are applied, as the existence of a hazardous atmosphere in a Division 2 location is itself considered a fault condition.

In the past, much of the nonincendive circuitry that found its way into Division 2 locations was neither designed nor intended for use in hazardous locations. Only when a Division 2 application arose for a specific item was the circuit examined to see if it was nonincendive. Regulatory bodies typically reviewed manufacturer's analyses to see if voltage and current levels fell below the appropriate ignition curve with a reasonable margin of safety. If they did, the circuit was accepted to be nonincendive.

Today, much of the equipment installed in Division 2 locations has been designed to be nonincendive. This is especially true of sophisticated electronic equipment used in the drilling industry. Furthermore, manufacturers are recognizing the value of independent third-party approvals. In North America, standard setting bodies, such as the Instrument Society of America, Underwriters Laboratories Inc., and the Canadian Standards Association, have published or are presently developing safety standards for nonincendive equipment. Third-party certification agencies are using these standards to evaluate and list or label nonincendive equipment.

Listed or labeled equipment provides the end user with a greater degree of confidence that the nonincendive equipment has been properly evaluated and will not present an unnecessary risk of fire or explosion. However, manufacturer certification of nonincendive circuits is acceptable; certification by a third-party testing agency is not required, and many acceptable nonincendive circuits bear no label or other marking by these agencies.

(2) <u>Intrinsically Safe Systems</u>. Section 500- 4(e) of the 1987 NEC states: Intrinsically safe apparatus and wiring shall be permitted in any hazardous (classified) location for which it is approved. Intrinsically safe equipment and wiring shall not be capable of releasing sufficient electrical or thermal energy under normal or abnormal (emphasis added) conditions to cause ignition of a specific flammable or combustible atmospheric mixture in its most easily ignitable concentration. Additional guidance on intrinsically safe installations is expected to be included in Article 504 of the NEC.

3.G.17.h (2) (cont'd) Intrinsically safe portable battery-powered equipment, such as walkie-talkies and combustible gas detectors, are evaluated based on their internal circuitry. However, equipment that is interconnected to other equipment, such as to the vessel's electrical system, is evaluated on a system basis. Since evaluations for intrinsic safety consider failure modes, faults in connected apparatus such as power supplies, meters, and recorders (regardless of their location, i.e., hazardous or non-hazardous) may affect energy levels in the circuit, and are fully evaluated.

In determining available energy levels, abnormal conditions include opening, shorting, and grounding of wires connected to the enclosures in the intrinsically safe portion of the system. In North America, two "reasonable" simultaneous faults are considered in assessing available electrical and thermal energy. Industry standards give detailed criteria for determining reasonable failure modes. Evaluations usually involve an in-depth circuit analysis, supplemented by actual ignition testing.

Intrinsically safe systems and portable equipment must be tested and approved for the intended application by a nationally recognized testing laboratory. For installed systems, listing reports should be reviewed to ensure that restrictions placed upon the equipment by the certification agency are recognized in the installation. In general, switches and other simple devices that do not store energy can be in hazardous locations when used with approved intrinsic safety (Zener) barriers that limit the energy in the circuit.

(3) Installation. Safety also depends on proper installation. It is necessary to ensure that the system is connected correctly and that unsafe energy levels are not induced in intrinsically safe circuits by nearby non-intrinsically safe circuits. In evaluating intrinsically safe systems, it is important to know the restrictions imposed by the certification agency, and to have the installation information available that verifies that the restrictions, such as installed cable impedance, have been met. The following installation requirements should be followed:

(a) Cables for use in intrinsically safe installations should meet the standards of 46 CFR 60-1. However, since intrinsically safe circuits are inherently power limited, cable constructions other than those specified in 111.60 may be accepted, provided the cable has an adequate voltage rating.

Many specialty cable types, which are not constructed to meet the standards referenced in 46 CFR 111.60, are used in intrinsically safe circuits, particularly in industrial systems such as down-hole well testing instrumentation. Flame propagation is a concern with any cable that penetrates a deck or bulkhead. If a particular cable type is self-extinguishing, but cannot comply with the IEEE-45 or IEC 60332-3 (Cat. A) fire tests, then it may be run singly (not in or near bundles or cable trays with other cables).

3.G.17.h(3)

(b) Equipment in weather locations must be made watertight.

(c) Cable insulation must be compatible with the environment. Some installations may be in cargo tanks.

(d) As a general rule, conductors should be no smaller than #18.

(e) Cables for intrinsically safe systems must be isolated from other cables to prevent compromise due to induction or insulation breakdown. This is to be accomplished by maintaining two inch spacing, or by using grounded metal barriers or shielded cable.

(f) At a termination, intrinsically safe circuits must be isolated from other intrinsically safe circuits, other low-energy level circuits, and all power circuits (see ISA RP 12.6).

(g) More than one intrinsically safe circuit of the same system may be run in a multiconductor cable (see ISA RP 12.6).

(h) Cables containing conductors for intrinsically safe systems must not contain conductors of non-intrinsically safe systems.

(i) In general, an intrinsically safe barrier should be located in a non-hazardous location. If it is in a hazardous location, the barrier itself must be suitable for the location.

(j) Energy storing equipment must be explicitly approved by the certification agency when used with a barrier.

(k) Passive devices that do not store energy, such as switches, thermocouples, resistances, and LED's may be connected to barriers without further certification, provided they are not part of a unit containing other electrical circuits.

For low power applications, intrinsically safe systems offer advantages over "add-on" protection, such as explosion-proof or purged and pressurized enclosures.

A missing or loose bolt, a scratched flange, an unpoured cable seal, a stuck interlock, or mechanical damage does not jeopardize intrinsic safety. The intrinsically safe circuit is less maintenance dependent and provides a lifetime of protection with relatively little care.

Although the Electrical Engineering Regulations reference the 1976 edition of ISA RP 12.6 for cables in intrinsically safe systems, that standard may also be used for other aspects of intrinsically safe installations. The guidelines of the 1995 revision of this standard may also be followed. This later edition contains information on the combination of intrinsically safe apparatus under the entity concept, which allows users to determine acceptable combinations of intrinsically safe apparatus and connected associated apparatus that have not been tested and

3.G.17.h (3) (cont'd) approved for interconnection in such combination. This approach requires each intrinsically safe apparatus to have a control drawing that specifies parameters for the selection of the associated apparatus. The manufacturer provides the control drawing to specify the allowed interconnections between the intrinsically safe and associated apparatus.

i. Purged Or Pressurized Equipment. Purged or pressurized equipment and enclosures are permitted by the Electrical Engineering Regulations (46 CFR Subchapter J) for the protection of hazardous area equipment. The regulations require that this type of equipment be constructed to the National Fire Protection Association (NFPA) Standard 496, Purged and Pressurized Enclosures for Electrical Equipment.

Purged or pressurized systems pressurize the atmosphere within an enclosure with a non-hazardous gas (usually air from a non-hazardous location), thereby preventing the hazardous atmosphere from coming in contact with electrical equipment within the enclosure.

The NFPA standard addresses pressurized instrumentation and other small enclosures in Class I locations, power equipment enclosures in Class I locations, pressurized instruments and other small enclosures in Class II locations, and pressurized power equipment in Class II locations. The standard defines pressurization and purging as follows:

Pressurization: The process of supplying an enclosure with clean air or an inert gas with or without continuous flow at sufficient pressure to prevent the entrance of combustible dusts.

Purging: The process of supplying an enclosure with clean air or inert gas at sufficient flow and positive pressure to reduce to an acceptably safe level the concentration of any flammable gas or vapor initially present and to maintain this safe level by positive pressure with or without positive flow.

(1) Types. There are three types of purging protection in NFPA 496, Type X, Type Y, and Type Z. Type Z reduces the classification within an enclosure from Division 2 to nonhazardous. With type Z purging, a hazard is created only if the purge system fails at the same time that the normally nonhazardous areas become hazardous. For this reason, it is not considered essential to remove power from the equipment upon failure of the purge system.

Type Y purging reduces the classification within an enclosure from Division 1 to Division 2. The equipment and devices within the enclosure must be suitable for Division 2. This requires that the enclosure not contain an ignition source under normal conditions. Thus, a hazard is created within the enclosure only upon simultaneous failure of the purge system and of the equipment within the enclosure. For this reason, it is not considered essential to remove power from the equipment upon failure of the purge system.

Type X purging reduces the classification within an enclosure from Division I to nonhazardous. Because the probability of a hazardous atmosphere external to the enclosure is high and the

3.G.17.i (1) (cont'd) enclosure normally contains a source of ignition, such as a hot element or arcing contact, it is important that any interruption of the purging results in deenergizing the equipment. Also, it is essential that the enclosure be tight enough to prevent the escape of sparks. When type X purging is used in purged power equipment enclosures in Class I locations, power to the equipment should be immediately removed upon loss of pressurization, unless immediate loss of power would result in a more hazardous condition, such as not allowing for the safe shutdown of a process or system.

The NFPA standard presents some diagrams of acceptable installations for Types X, Y and Z purging. These diagrams are shown in 3.G.17.i(2). The NFPA standard requires that a nameplate be mounted on the enclosure in a prominent location so that it can be seen before someone opens the enclosure. The nameplate should contain the following statement (or equivalent):

"Enclosure shall not be opened unless the area is known to be nonhazardous or unless all devices within have been de-energized. Power shall not be restored after enclosure has been opened until enclosure has been purged for minutes." (Note: The blank must be filled-in by the manufacturer with the proper purge time).

It is apparent from this requirement that purged or pressurized enclosures should be designed in such a manner that normal operation of the equipment does not require that the enclosure be opened. Therefore, openings in the enclosures for inserting computer disks or slots for computer printouts and normal procedures that require the enclosure to be opened to retrieve data or take readings is not acceptable.

All three types of purging require the warning nameplate. Type X purging generally requires an interlock that immediately de-energizes all circuits that are not suitable for Division 1 areas. Type Y purging does not require an interlock but requires an alarm which operates when the enclosure is opened. Type Y is suitable for Division 1 if the internal components are suitable for Division 2. Type Z purging is suitable for Division 2 and requires an alarm, but does not place restrictions on internal components.

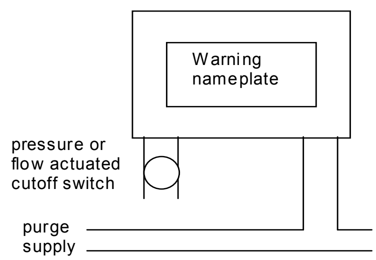
Purged or pressurized equipment may be used in lieu of explosion-proof equipment for all hazardous locations. Purged or pressurized equipment may not be used as a substitute for intrinsically safe apparatus. Purged or pressurized systems need not be approved by an independent testing agency, but are reviewed and approved for the particular application during vessel plan review.

Special care must be taken to ensure that the protective gas is from a non-hazardous source and cannot be contaminated by a hazardous source. Vent fan operation should be monitored by airflow, not simply by motor operation. Where it is necessary to open a purged or pressurized enclosure, for maintenance/repair, gas detection equipment maybe required so that a flammable atmosphere does not become trapped within the enclosure.

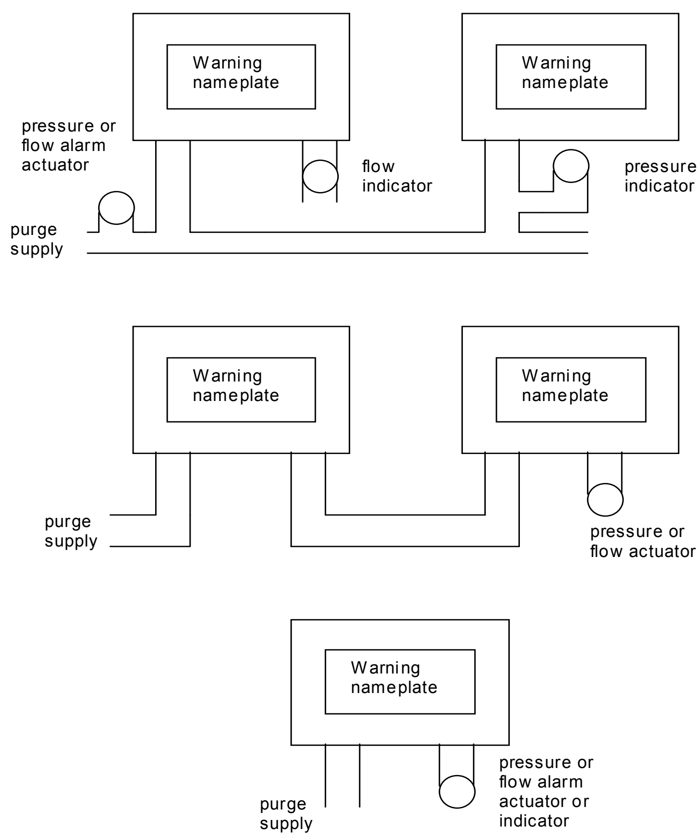
3.G.17.i (1) (cont'd) NFPA 496 recognizes the use of purged control rooms in Class I locations and pressurized control rooms in Class II locations. The requirements for control rooms may be used both for spaces that are structurally part of the vessel and for containerized compartments such as may be used for industrial functions aboard a MODU. Compressed air operated lighting fixtures (turbine lights) are both powered and purged by the air supply. These fixtures are acceptable for use in cargo handling rooms.

(2) <u>Purged and Pressurized Drawing</u>.

Typical Type X Purging



Typical Type Y and Type Z Purging



j. <u>Explosion-Proof Equipment</u>.

(1) <u>Enclosures</u>. When electrical equipment is installed where flammable gases and vapors may be present, an "explosion-proof"

3.G.17.j (1) (cont'd) enclosure may be used to allow the equipment to operate safely. The explosion-proof enclosure concept recognizes that flammable gases and vapors may enter the enclosure, and assumes that a source of ignition will create an internal explosion. The enclosure is designed to withstand the explosion and prevent it from propagating to the hazardous atmosphere surrounding the enclosure. Explosion-proof enclosures are not designed to be gastight, but are normally intended to "breathe." Flammable gases or vapors may enter an enclosure as it breathes due to changes in atmospheric pressure, ambient temperature, or both.

Conversely, gastight equipment is not explosion-proof. Explosion-proof enclosures usually have covers that can be removed or opened for making connections and adjustments, and for maintenance. The dimension of the gap between an enclosure's flanges and metal-to-metal joints determine its effectiveness. An explosion will propagate through this gap if the gap's width is greater than the maximum experimental safe gap (MESG). If the gap is less than the MESG, the velocity of the emerging jet of hot gases and the velocity of the external gases mixing with the jet are so great that cooling takes place and ignition cannot occur. When the hot gases from an explosion pass through this region, some energy is absorbed by the expansion of gases (refrigeration effect), and hot gases mixing with cool gases outside of the enclosure absorb some energy. Sufficient amount of energy must be transferred from the hot gases to the surrounding air or enclosure; otherwise, an explosion will occur.

Several explosion-proof enclosure cover types are used, depending on their application. The most simple and effective cover is a threaded joint. When an explosion occurs, the cover threads are forced tight against the body threads. Hot gases are cooled as they spiral along these threads. A gasket under the cover's flange is located outside of the cooling region and does not interfere with the metal-to-metal contact of the threads. Other types of enclosure openings or accesses include flanged and cylindrically shaped openings. These enclosures use precision-machined metal-to-metal joints that provide a straight path from inside the enclosure to the outside atmosphere. During an explosion, numerous cover screws prevent flange and enclosure distortion. Explosion-proof equipment in weather locations must be made watertight or waterproof. Explosion-proof enclosures are not normally designed to be watertight. In making these enclosures watertight, care should be taken that there is not interference with the flame-quenching surfaces and that gaskets are external to these surfaces.

When a flame ignites a gas, it may result in an explosion that causes a large increase in pressure. Due to the rapid increase in pressure, less energy is required for further ignition and flame propagation. An explosion occurs rapidly, causing a front between burned and unburned compressed gas. If the expanding gas is restricted, channeled, or impeded, pressure piling will occur. Pressures can occur which are ten times higher than pressures that occur when there is no impediment to expansion. Pressure piling is particularly serious in pipes and conduit. To reduce the effects of pressure piling, cable seal fittings must be

3.G.17.j (1) (cont'd) installed within eighteen inches of the enclosure for each conduit. Where two explosion-proof enclosures are connected and located less than 36 inches apart, only one seal is necessary in the conduit between them.

(2) Equipment. Equipment which is required by the Electrical Engineering Regulations to be explosion-proof must be specifically tested and approved by a nationally recognized testing laboratory for use in a Class I Division 1 location and the group of the hazard present, and be labeled as such.

In typical test programs, the enclosure is placed in a test chamber that has explosion pressure-recording devices attached to it. Both the enclosure and the chamber are charged with a specified gas. The gas inside the enclosure is ignited, and the resulting explosion is observed for propagation to the surrounding chamber's atmosphere. The explosion tests are repeated over the entire explosive range of the gas or vapor's fuel-air mixture. The enclosure must withstand the internal pressure from the explosion without bursting or loosening its joints. Explosion damage to equipment inside the enclosure must not occur during testing unless the damaged equipment can readily be replaced. All tests are conducted using maximum loads, short circuit, or worst-case conditions. Typically, ten tests are conducted over the entire flammable range for each device. Enclosures are tested for a period of one (1) minute using a hydrostatic pressure based on the max observed internal explosion pressure. Seals must withstand for one (1) minute a hydrostatic test pressure of four times the maximum explosion pressure.

Equipment that generates heat is evaluated to ensure that its surface temperature is not high enough to cause auto-ignition of the surrounding hazardous atmosphere. North American practice recognizes 14 temperature ratings for Class I locations. The Class I temperature ratings are listed in NEC Table 500- 5(e) and the Class II temperature limits are in NEC Section 500- 5(f).

TABLE 3
NEC ART. 500 - TABLE 500-3(b)

MAX. TEMP		
°C	°F	MARKING
450	842	T 1
300	572	T 2
280	536	T 2 A
260	500	T 2 B
230	446	T 2 C
215	419	T 2 D
200	392	T 3
180	256	T 3 A
165	329	T 3 B
160	320	T 3 C
135	275	T 4
120	248	T 4 A
100	212	T 5 *
85	185	T 6 *

Marking shall not exceed auto ignition temp of the atmosphere encountered.
* Non-heat producing equipment, with a temp of 100°C or less, need not be marked.

3.G.17.j(2)

(a) Flame Arresters. Flame arresters are sometimes used in explosion-proof enclosures to reduce maximum explosion pressure and to protect any incoming air lines. Types of flame arresters include porous metal plugs made of sintered metal, a baffle-type breather similar to an automobile muffler, a special fitting with a loosely fitted thread, and a spiral wound corrugated metal fitting. These configurations causes the flame to spread through paths which cool the gases by heat transfer to the metal from the atmosphere or make the escaping explosion's hot gases turn sharp corners, allowing them to cool.

(b) Explosion-Proof Receptacles & Plugs. Explosionproof receptacles and plugs are designed as a pair. Mechanical interlocking is used between the plug and receptacle. When a plug is inserted, electrical contact cannot be made until the automated plug and receptacle assembly has established its explosionproof integrity. To prevent explosions from propagating, many threads are usually engaged before electrical contact is made or broken.

An explosionproof enclosure is not effective without sealed conductor entrances. Seal fittings allow an explosion to be contained within an enclosure; to prevent pressure piling and prevent the transmission of gases or vapors between enclosed electrical systems install in Division 1, Division 2, and ordinary locations. Seal fittings are usually attached by a short piece of rigid conduit to an enclosure for switches, circuit breakers, fuses, relays, resistors, or other apparatus which may produce arcs, sparks, or a high temperature. Not more than eighteen (18) inches of pipe or rigid conduit may be used, and at least five (5) full nipple threads must be engaged at each end. Explosionproof unions, couplings, elbows, capped elbows, and conduit bodies are the only permitted fittings between the sealing fitting and the enclosure. All such components, including the seal fitting and seal compound, must be approved by the testing laboratory for the intended purpose. Seal fittings are either shop fabricated or poured in the field. The cable gland is a relatively new type of seal. Use of a cable gland allows for a cable to be assembled in a clean shop environment and for simple field connection and installation. A more traditional sealing method uses a "poured" seal, which is completed in the field. The seal is poured after the cables have been brought into the enclosure. Mineral insulated cables require a different type of explosionproof seal fitting than shipboard marine cables.

k. Alterations &/or Repairs. Alterations to explosionproof equipment may destroy explosionproof protection. Explosionproof enclosures approved for certain applications, such as the installation of terminal strips, relays, etc., and may be internally modified to meet these intended applications within the limits specified in the approval. Explosionproof assemblies may not be modified in any way.

Enclosure modifications must are limited so that they do not affect piling from internal volume changes, impair flame-quenching paths and

3.G.17. k. (cont'd) surfaces, or reduce enclosure structural strength. Alterations different from the configuration, as tested by UL, FM, CSA, or other approved laboratories, void the approval.

Equipment that is certified for hazardous locations should usually be repaired by a qualified facility. Product certification agencies usually qualify repair facilities that have demonstrated their knowledge, expertise, and capability to repair explosionproof equipment. Each facility is qualified to repair specific types of equipment such as motors, generators, telephones, etc.
When the explosionproof equipment is repaired, a label is usually affixed to indicate that the equipment conforms to the same rules that applied when it was new. The following guidelines can be used to maintain explosionproof equipment:

(1) All cover screws and bolts must always be tight while circuits are alive. Leaving one screw or bolt loose can render equipment unsafe. Bolts or screw types other than those provided with the equipment should not be used.

(2) Hammers and other tools must not be allowed to damage threaded joints or flat machined surfaces of flanged joints. All surfaces that form part of a flame path must be protected from scratches and other mechanical defects.

(3) Flange surfaces and threaded joints should be cleaned free of old grease and other foreign materials. An appropriate light non-flammable lubricant should be applied to both sides of the joint immediately before assembly. When reassembling, there should be no foreign particles on joint surfaces.

(4) Threaded covers, flat joints, surfaces, rotating shafts, bearings, and operating shafts should be lubricated to protect against corrosion. Abrasives or files should never be used to remove corrosion products from threaded or flanged joints. Equipment that is corroded should be replaced.

(5) Explosionproof equipment must not be modified, except as allowed by the approval laboratory, and the equipment nameplate should not be obscured.

18. Industrial Systems (46 CFR 111.107).

a. Philosophy. Subpart 111.107 of the Electrical Engineering Regulations states that systems on Mobile Offshore Drilling Units that are used solely for the industrial function of the unit (drilling) may be considered as industrial systems. Industrial systems need not be restricted to MODU's, nor must they be related to petroleum exploration and exploitation functions; the concept of industrial systems can be extended to systems, which serve only an industrial function on other types of vessels. Subchapter F, Marine Engineering, 46 CFR 56.01-1(c), provides alternative requirements for piping and pressure vessels in industrial systems on MODUs. However, the Marine Safety Manual indicates that this can be extended to other vessels in individual cases under the general equivalency regulations if the designer prefers to meet the requirements of 58.60. Similarly, 111.107 can be extended to other industrial systems. An example of

3.G.18. a. (cont'd) such an industrial system is the crane power generation and distribution system on a craneship. Unlike the machinery (piping) design, the electrical aspects of industrial systems are not covered by a registered professional engineer's certification. Compliance with 46 CFR 111.107 must be established by plan review and/or inspection.

b. Generators. Industrial systems may be provided with dedicated generators or they may be supplied by the ship's service power distribution system. Where any generator, installed or portable is tied to the main switchboard so that it can be used to provide ship's service power, that generator must be considered a ship's service generator. The generator and switchboard regulations contained in 46 CFR Subparts 111.12 and 111.30 would then be applicable, as would the requirements for fault current analysis and (possibly) automatic load shedding. Dedicated industrial system generators, including containerized generator sets which are not tied to the main switchboard and have no provision to supply any ship's service loads, need, from an electrical standpoint, only meet the general safety criteria of the National Electrical Code and 46 CFR Subpart 111.107. Note that as discussed in 3.G.19.a, the emergency generator is not intended to be used as an "in port generator".

19. Emergency Lighting and Power Systems (46 CFR 112).

a. General. SOLAS II-1/42, 43, and 44 contain the requirements for emergency lighting and power systems, as does 46 CFR 112. These two sets of requirements (USCG and SOLAS), are generally in agreement. Vessels in some categories are permitted shorter periods of operation of the emergency power supply by 46 CFR Table 112.05-5(a) than by the SOLAS regulations; these vessels would not normally carry SOLAS certificates due to their size and/or limited operating routes. The Electrical Engineering Regulations permit manually connected emergency power sources only for cargo vessels less than 500 GT or cargo vessels of less than 1600 CT on other than ocean, Great Lakes, or coastwise routes and not on international voyages.

Diesel and gas turbine engines used as emergency generator prime movers must be capable of starting at an ambient temperature of 32 degrees F (0 degrees C). Electric water jacket heaters are permitted to ensure ready starting. Due to the impracticality of testing this capability in warm climates, the manufacturer's certification is generally accepted. A thermostatically controlled electric lubricating oil heater may be provided to reduce the accelerated wear, which may result from placing the generator load on a cold engine. Where detached electric motor-driven pumps are provided to circulate warm oil through the engine while it is stopped, a low oil level alarm should be installed to indicate any loss of oil through a leak in the pumps or external piping.

SOLAS 11-1/44.2 requires each emergency generating set to be equipped with a starting device with a stored energy capability for at least three starting attempts, with a second source for an additional three starts to be provided within 30 minutes unless manual starting (not just manual initiation of the start per 46 CFR 112.35-5) is practicable. This differs somewhat from the Electrical Engineering Regulations. The requirements for hydraulic, electric, and compressed

3.G.19. a. (cont'd) air starting Systems in 46 CFR 112.50 call for a capacity for at least six cranking cycles, with the capacity for three of these cranking cycles to be held in reserve until manually released.

The emergency generator is not intended to be used as an "in port generator"; it may be used to supply necessary electrical power to start the ship's machinery plant from a dead ship condition. When used in this manner, the emergency generator must be sized to provide power to all required emergency loads in addition to any loads on the emergency switchboard (not bus-tie loads) that are used for starting the ship's main propulsion machinery.

b. Location. SOLAS II-1/42.1.3 and 43.1.3 and 46 CFR 112.05-5(e) all state that the emergency generator room and a category A machinery space should not be adjoining, except where other arrangement is not practicable. Note that the CFR specifies the spaces will not be "adjoining", SOLAS requires not "contiguous", both indicating the spaces will not border each other horizontally or vertically. The intent is to maintain the integrity of the emergency electrical distribution system if there is a fire, flooding, or other casualty in the main machinery space. When the arrangement has been shown to be impractical, the installation of an A-60 bulkhead between the emergency generator room and the category A machinery space has been accepted.

It is recommended that the steel bulkhead be insulated to A-60 on both sides. Any contiguous boundary between the emergency generator room and any category A machinery space or space containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard must be avoided.

c. Emergency Loads. The temporary and final emergency loads listed in 46 CFR Subpart 112.15 must be supplied by the emergency power source(s). Additional safety devices and systems (i.e., vital) may be connected to the emergency power system provided the emergency source is sized to supply these loads at 100% load factor. Additional loads which are intended to improve the safety or survivability of the vessel in certain operating modes (i.e., non-vital) and which have not been considered in sizing the emergency generator (such as the addition of a secondary deballasting system on a semisubmersible MODU) may be allowed to be connected to the emergency power supply when arranged to be functionally equivalent to a bus-tie - configuration. The following conditions would apply:

The non-vital loads must automatically trip off the emergency switchboard by means of an undervoltage or underfrequency trip or equivalent. When the normal power supply is lost; these loads must only be manually reconnected to the emergency bus, (this may be done remotely) and the non-vital loads must be shed automatically prior to overloading of the emergency generator. On a case-by-case basis, the emergency power system may be used to supply non-emergency circuits such as bilge pumps that are provided on Open-top Containerships to dewater cargo holds. These pumps are considered non-vital in the sense that with all the holds flooded, the ship is still seaworthy. With these additional non-emergency pump motor loads connected to the emergency bus, acceptable measures must be taken to safeguard independent emergency operation of vital loads under all

3.G.19. c. (cont'd) circumstances. Remote load monitoring and manual disconnection of required emergency loads is allowed, but automatic load shedding of the non-vital loads is necessary to maintain the integrity of the emergency power system.

Secondary Deballast Systems on MODUs may be electrically connected to the emergency switchboard via a transfer switch. This transfer switch may be an automatic bus transfer switch provided automatic load shedding is provided. Or manual if the emergency generator is sized to carry all the loads attached to the emergency bus. Upon shifting to emergency power, the Secondary Deballasting System must only start by manual initiation. This manual starting may be accomplished from the vessel control room.

None of the regulations in Subchapter J prohibit manually disconnecting required emergency loads at the operator's discretion. This may be accomplished via a remote start/stop switch located in the vessel control room.

Sizing of the Emergency Generators on Open-Top Containerships: Neither SOLAS consolidated edition 2001 nor ABS Rules require the emergency generator to be sized to supply the total connected load. Also, neither rule prohibit the connection to the emergency source of power, loads not specified in the requirements. SOLAS consolidated edition 2001, Chapter II-1, Regulation 43.2 and ABS rule 4-8-2/5.5 merely require the electrical power available to be sufficient to supply all those services that are essential for safety in an emergency with due regard given to those services that may be operated simultaneously. SOLAS consolidated edition 2001, Chapter II-1, Regulation 43.1.4 permits the emergency generator to be used to supply non-emergency circuits from the emergency switchboard "provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances".

On an open-top containership conversion, the owner proposed to power the open-hold bilge pumps through manual transfer switches which would allow the pumps to be supplied from both the main and the emergency switchboards. There must also be an automatic means of disconnecting the pumps from the emergency switchboard when there is a failure of the main source of power.

Any bus-tie between a main switchboard and an emergency switchboard must not have automatic feedback of power from the emergency source to the main switchboard. When operating in a feedback mode, the bus-tie must open automatically upon overload before the emergency power source is tripped off line. Each bus-tie should be provided with short-circuit protection by a circuit breaker or fuses at both the main and the emergency switchboards.

Cables from the emergency switchboard, other than those which supply equipment in the machinery spaces, must not be run through the engineroom, boilerroom, or the casings of these spaces. Emergency power cables must not be run along decks or bulkheads that form the boundaries of these spaces. Again, the intent is to maintain the integrity of the emergency power system by protecting emergency power cables from thermal damage should there be a fire in the machinery spaces.

3.G.20. Communication and Alarm Systems.

a. Fire detecting And Alarm Systems. An automatic fire detecting and alarm system consists of a power supply, a control unit on which are located visible and audible fire and trouble signaling devices, and fire detector and alarm circuits, as required, originating from the control unit. Detector and alarm circuits consist of initiating and indicating devices and alarms. Initiating devices are smoke, heat or flame detectors and manual fire alarm boxes. Indicating devices are audible and visual alarm devices such as bells and strobe lights.

The Coast Guard approves systems on two separate levels. Fire detection system manufacturers obtain "Type-approval" of a system meeting the requirements of 46 CFR 161.002 from the Commandant (G-MSE-4). All of the components that compromise the system must be incorporated in the type approval submittal. Systems are approved for use on individual vessels by the Marine Safety Center based on compliance with the manufacturer's type system approval. Approved systems are required in designated areas of Passenger Vessels (46 CFR 76.05), Cargo and Miscellaneous Vessels (46 CFR 95.05), and in machinery spaces of inspected vessels where automated systems are provided to replace manual control and observation, such as minimally attended machinery spaces with centralized control rooms or unattended machinery spaces (46 CFR 62.50-20(c) and Table 62.35-50). Approved Systems are also required in cargo spaces intended for the carriage of dangerous goods per SOLAS 74, as amended, Regulation II-2/54. NVIC 7-80 "Use of Fire Detection Systems Which Are Not Approved under 161.002" must be consulted for guidance on systems for areas where detectors may be installed but are not required.

Listing by an U.S. Coast Guard recognized independent testing is not sufficient evidence of compliance with the type-approval requirements found in 46 CFR 161.002. Approval of systems designed for specific vessels may be obtained from Commanding Officer, Marine Safety Center, U.S. Coast Guard, 400 7th St. S.W, Room 6308, Washington, DC 20590-0001. Arrangements of the systems must be submitted in triplicate and all approved components should be readily identifiable. Only approved components should be used.

The requirements for location of equipment for all systems are found in 46 CFR 76.27 and 35. Additional requirements for vessels requiring SOLAS Certificates are found in SOLAS 74, as amended, Chapter II-2. Further guidance on locating detectors can be found in NFPA 72. Ventilation effects should be considered when locating detectors. 46 CFR 76.33 describes the allowable area to be monitored by an accumulator. Accumulator spacing may vary based on the fire detection system manufacturer's assurance that the spacing as proposed will provide adequate coverage of the spaces concerned.

b. General Alarm. A general alarm system meeting 46 CFR Subpart 113.25 must be provided on each manned vessel of over 100 gross tons, except barges, scows and similar vessels to alert the crew and passengers to the existence of an emergency situation and the need to report to their muster stations. Components of the general alarm system, including vibrating bells and flashing lights, do not require type approval by the Commandant. Only the system design and equipment installation need now be approved.

3.G.20 b. (cont'd) The general alarm must only be initiated manually and is intended to be sounded by the person on watch or other responsible member of the crew only after the determination has been made that an emergency situation exists which warrants mustering the crew and passengers (if any). SOLAS II-2 Regulation 13.1.4 permits the general alarm to be sounded automatically by a safety monitoring system, such as a fire detection and alarm system, if an initiating fire alarm is not acknowledged within a reasonable time (two minutes). This is permitted for spaces other than passenger spaces.

An integrated general alarm, fire alarm and public address system may be considered for equivalence to the intent of 46 CFR 113.25 and to satisfy SOLAS Chapter II-2, Regulation 40.5 for a public address system. Any such arrangement must give priority to the general alarm function. Such a system would function similarly to the multi-purpose 1MC Emergency Announcing System commonly used on naval vessels. Speakers and electronic tone generators may be used to produce a bell-like signal or tone distinct from any other audible signal on the vessel. The location of speakers and the generated sound level must meet 46 CFR 113.25-9. Either a distinct sound signal or intermittent operation of the general alarm bells (or speakers producing bell-like sounds) may be used to warn of fire. An integrated system must meet the following criteria:

(1) The fire alarm activating switch must be in a normally manned space, which can receive alarms from the master fire alarm panel and which has a general alarm contact maker.
(2) The general alarm signal must have priority over the fire alarm signal.
(3) The fire alarm switch should be marked "Fire Alarm" in red letters on a corrosion-resistant plate or sign.
(4) Operation of the fire alarm switch may also activate a fire alarm page via the public address system. This must not interfere with the normal operation of the general alarm.
(5) If the fire alarm signal is generated external to the general alarm system, loss of power to it must not affect the general alarm system.
(6) The fire alarm signal must be distinct from those signals required by 46 CFR 109.503 for MODUs.

The emergency signals required by 46 CFR 109.503 for Mobile Offshore Drilling Units differ considerably from those used on other types of vessels. The intent of this was to recognize and standardize existing industry practice that was different than for vessels.

This promotes consistency among offshore rigs, both mobile and fixed, so that an offshore oil worker can recognize the same sound signal and respond in the proper manner to similar emergency situations on either kind of installation. The emergency signals specified in 46 CFR 109.503 should be used for "emergency stations" and "abandon unit" situations only.

c. MODU’S. Other signals, such as fire warnings, must be distinct from these required signals. Vessels have been allowed, on a case-by-case basis, more than one general alarm contact maker in addition to those required under 46 CFR 113.25-5(a), (b), or (c) where justification was presented. Additional contact makers may be permitted where their

3.G.20 c. (cont'd) installation results in an increase in vessel safety. Any additional contact makers should meet the construction requirements of 46 CFR 113.25-11 and should be labeled per 113.25-20(b). Contact makers in weather locations should be provided with suitable weatherproof enclosures. Where jack boxes are used for these additional contact makers, there must be cut-out switches in the wheelhouse that can isolate the jack boxes from the rest of the general alarm system.

There are no switches available which satisfy the requirements of both 113.25-11 for contact makers and 111.105 for electrical equipment in hazardous areas. For contact makers that must be in hazardous locations, the requirements of 111.105 apply. These switches should be labeled as required for contact makers by 113.25-20(b) and 113.25-11(d), as applicable.

Flashing red lights which augment the general alarm bells must be supplied by the general alarm system power supply, except for flashing red lights in the main machinery space supplied from the emergency source of power through relays operated by the general alarm system. In general, the use of the emergency source of power for all general alarm system flashing red lights meets the intent of 113.25-10(c).

d. Alarm Signals. The minimum sound pressure levels for the emergency alarm tone in interior and exterior spaces must be a sound level of not less than 80dB(A) measured at 10 feet on the axis; and at least 10dB(A) measured at 10 feet on the axis, above the background noise level when the vessel is underway in moderate weather unless flashing red lights are utilized in accordance with 113.25-10(b) of this subpart. Alarm signals intended for use in sleeping compartments may have a minimum sound level of 75dB(A) measured 3 feet (1m) on axis and at least 10dB(A) measured 3 feet (1m) on axis, above ambient noise levels with the ship underway in moderate weather.

e. Sound Powered Telephones. Section 37.22 of IEEE Standard 45 and military specification MIL-T-15514 may be used as guidance for construction, installation, and performance standards for sound-powered phones.

Sound-powered telephone headsets and jack boxes are not permitted on any telephone system that includes any station required by the regulations, except for use at engineroom local control stations; see 46 CFR 113.30-20(c). The objections to the use of these portable headsets are:

(1) Headsets are often not there when needed.
(2) Headsets have been more prone to damage than fixed handsets.
(3) Headsets introduce noise on the circuit because the earphone is always on and acts as a microphone.
(4) Jack boxes frequently corrode and short the circuit contacts, causing unreliable circuit operation.

A hard-wired (no jack) headset with a push-to-talk button, a watertight storage/connection box, and a cut-out switch can overcome these objections and may be accepted for use in locations with high background noise~levels, such as steering gear rooms.

3.G.20. f. Engine Order Telegraph (EOT, 46 CFR 113.35). The engine order telegraph is a communication system that is necessary under temporary emergency conditions. Where an electric EOT is installed, 46 CFR 112.15-1(h) is applicable. Electric EOT systems must either be provided with an independent storage battery source of backup power or be arranged so that they can be energized from the temporary emergency power source. 46 CFR 113.35-5 also contains additional requirements for an electric EOT.

46 CFR 113.35 requires the EOT transmitter in the wheelhouse to have a "handle." The intent is to provide for rapid visual determination of engine order from throughout the wheelhouse, and if necessary, a determination by feel. This intent should be met by an EOT considered a secondary or standby device, as well as an EOT used as a primary control device. In most instances, this precludes consideration of a flush mounted, knob-type transmitter as an equivalent arrangement. Transmitters that provide rapid visual and tactile determination of orders, such as some push-button type transmitters, may be evaluated for equivalency.

g. Emergency Loudspeaker Systems. Subpart 113.50 of the Electrical Engineering Regulations requires an emergency loudspeaker system on each ocean and coastwise passenger vessel certificated to carry 500 or more persons, including officers and crew, and each passenger vessel that has lifeboats stowed more than 100 feet (30.5 meters) from the navigating bridge. The system permits two-way conversation between the navigating bridge and each lifeboat or embarkation station. SOLAS Chapter III, Regulation 6.4.1 requires an emergency means of two-way communication between emergency control stations, muster and embarkation stations, and strategic positions on board as part of the lifesaving arrangements for both passenger and cargo ships.

A combined public address, music distribution, and emergency loudspeaker system may be used for the system required by 113.50, provided the emergency loudspeaker function is given priority. If a separate public address or music system is used, a means to silence that system must be provided at the emergency loudspeaker system control panel.

H. Novel Vessel Design.

1. High Speed Craft. Rapidly occurring changes in technology often require the adaptation of existing requirements to new situations. Dynamically supported craft such as hydrofoils, surface effect ships, and air cushion vehicles are unique vessel designs that likely will require research and evaluation on an individual basis. The Marine Safety Center leads the concept review of novel designs and will determine what guidance to apply. Modern vessels operating over a 30 knot threshold will likely be classified as a high speed craft, particularly if they are engaged in passenger service. Coast Guard guidance for domestic high-speed craft can be found in: “Guidance for Enhancing the Operational Safety of Domestic High-Speed Vessels”, COMDTPUB P16700.4, NVIC 5-01. Coast Guard guidance for vessels built to international standards can be found in: “Plan Review, Inspection, And Certification Guidance For Vessels Built To The International Code Of Safety For High-Speed Craft And Additional Information Regarding Non-Code High-Speed Vessels”, COMDTPUB P16700.4, NVIC 6-99.

3.H.2 Deep Water Ports (DWP's).

a. Introduction. The Federal Register Volume 69, dated 06 January 2004, page 724, institutes a Temporary Interim Rule for Deep Water Ports. The Federal Register is available online at: http://www.gpoaccess.gov/fr/index.html . For general information on offshore platform regulations see Volume II, Section B, Chapter 8, of this manual. The involvement and responsibilities of Commandant (G-MSE-3) with DWP's has primarily been to provide electrical technical assistance. This assistance was needed as a result of 33 CFR 149.205(c), which states that "each electrical installation on a platform must be designed, to the extent practicable, in accordance with 46 CFR 110-113." Commandant (G-MSE-3) became increasingly involved with the DWP project upon issuance of Final Deepwater Ports Regulations, Subchapter RN, on 10 November 1975. Since the Electrical Engineering Regulations (Subchapter J) are referenced therein, interpretations of their requirements (e.g., "to the extent practicable") were necessary. The "exemption petition" procedures were established by the DWP project, and many of these were considered and acted upon by the branch's electrical staff. Interpretations regarding the application of Coast Guard Shipboard Electrical Regulations to the fixed structure of a deepwater port were made each time an "exemption petition" was considered.

b. Loop Project. The most involved "exemption petition" concerned a request from the Louisiana Offshore Oil Port (LOOP) for relief from the use of Subchapter J for classification of hazardous areas. LOOP proposed to use the American Petroleum Institute's (API's) recommended practice (API RP 500B), strengthened by the other rules of typical industry practice. The focal point of the difference is that Coast Guard regulations assume hazardous concentrations of flammable vapors to exist periodically in the vicinity of cargo pipe flanges, pumps, and valves because of leakage. This assumption renders the spheres within 10 feet of these fittings as Class 1, Division 1, while "the industry standard" assumes the vapors will be contained in the cargo piping, escaping only in case of abnormal operation at breakdown (Class 1, Division 2). After several appeals, the decision to enforce the Coast Guard regulations was made. Significant exemptions that have been granted to LOOP are as follows:

(1) UL 57 electrical lighting fixtures (industrial standard) have been allowed for installation inside the control building in lieu of UL 595 marine fixtures;

(2) Cable requirements have been relaxed where conduit systems are used, provided certain criteria are met;

(3) Silicon dielectric-type transformers have been allowed for certain applications if dry-type transformers are not available;

(4) Ship motion and other strictly shipboard-related requirements have been deleted where judged inappropriate or not practicable;

Special requirements have been set for the higher voltage systems used on the deepwater port.